CHOICE OF TECHNOLOGY IN RICE HARVESTING IN THE MUDA IRRIGATION SCHEME, MALAYSIA

BY

AHMAD MAHDZAN BIN AYOB

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1980

ACKNOWLEDGMENTS

The author would like to express sincere appreciation to Dr. W. W. McPherson, Chairman of his Supervisory Committee, for his advice and contributions in the preparation of this dissertation. Dr. McPherson's work was made more difficult as most of the preliminary drafts had to be mailed back and forth between Gainesville and Petaling Jaya, Malaysia, in the early stages of the research project. Special thanks are due to members of the Committee, Dr. M. R. Langham, Dr. R. D. Emerson, Dr. J. E. Reynolds and Dr. F. O. Goddard, for their contributions.

The collection of the primary data was generously supported by the Agricultural Development Council, New York, through the efforts of Dr. Donald C. Taylor, A/D/C Associate in Malaysia and Dr. Hans P. Binswanger, A/D/C Associate at ICRISAT, India. The author thanks Don and Hans for having started his interest in agricultural mechanization. A note of thanks is also extended to the author's colleague and Dean, Dr. Radzuan A. Rahman, for his continued interest and support in this research.

The surveys in Muda were facilitated by the helping hands of MADA officials. The author is grateful to Dr. Afifuddin Hj. Omar and Mr. S. Jegatheesan of MADA Headquarters for their assistance during the fieldwork. Thanks also go to Encik Md. Taib bin Hj. Din, Encik Mohammed bin Lazim and Encik Abu Bakar bin Hamid, FA General Managers in Kodiang, Titi Hj. Idris and Permatang Buluh, respectively, for their cooperation. To the obliging farmers in Muda, "Terima kasih!"

The supervision of the fieldwork was assisted by the author's two able colleagues, Encik Zainal A. Tambi and Encik Wan A. Rahman, for which his sincere appreciation is recorded.

The author is grateful to Ms. Nancy Melton who helped with the use of the computer at the University of Florida. A similar note of appreciation must also go to Mr. Choong Kooi Yoon at the University of Malaya Computer Center in Kuala Lumpur for assisting in many preliminary runs. Computer time at the University of Florida was provided by the Food and Resource Economics Department.

Cik Noraini Mohammed skillfully typed the first draft in Malaysia, portions of which were retyped by Ms. April Burk and Ms. Pat Smart in Gainesville. Ms. Janet Eldred typed the final version with meticulous accuracy. Thanks to all of them.

A special note of thanks goes to the author's friend, Dr. Jonq-Ying Lee, at the University of Florida for his many kindly gestures and moral support throughout Winter 1980.

The author is deeply grateful to Universiti Pertanian Malaysia for providing financial support and study leave to enable him to go through the doctoral program at the University of Florida.

Last but by no means least, the author would like to express his utmost gratitude to his wife and their children for their love and understanding through very trying moments during this final leg of the "academic marathon." To his wife and children the author dedicates this work.

TABLE OF CONTENTS

		Page
ACKNOWLEDGMENTS		ii
LIST OF TABLES		vii
LIST OF FIGURES		x
ABSTRACT		xi
CHAPTERS		
I	INTRODUCTION	1
	The Problem	1
	Objectives	4
	Importance	5
	Sources of Data and Analytical Tools	6
	Sources of Data	6
	Analytical Tools	7
	The Malaysian Setting	7
	Agriculture	7
	Paddy Subsector	9
	Double-cropping	14
	The Muda Irrigation Scheme	16
	Plan of the Dissertation	20
II	LITERATURE REVIEW	22
	Theory of Technical Change	22
	Choice of Technology	28
	Diffusion of Technology: The Empirical Literature	31
	Economics of Mechanization: The Empirical Literature	42
III	METHODOLOGY	49
	Introduction	49
	Ex-ante Considerations	49

TABLE OF CONTENTS (Continued)

		Page
	Farm Size (x_1)	51
	Schooling (x_2)	52
	Tenure Status (x_3, x_4)	53
	Fragmentation (x_5)	55
	Sex of Respondent (x_6)	57
	Perception of Economic Advantage (x_7)	57
	Perception of Better Grain Recovery (x_8)	57
	Neighborhood Effect (x_9)	58
	Age (x_{10})	59
	Labor Availability (x_{11})	59
	Full-time Status (x_{12})	60
	Farmers' Association Membership (x_{13})	60
	Summary of Hypotheses	60
	Measurement of Variables	62
	Dependent Variables	62
	Independent Variables	62
	Analytical Procedures	65
	Logistic Regression	65
	Tobit Analysis	68
	Sampling Procedures	68
	Farmer Sample	68
	Labor Sample	73
	Combine Harvester Owner Sample	73
	Combine Harvester Brokers	76
	Characteristics of the Sampled Localities	76
IV	ANALYSIS OF RESULTS	80
	Choice of Technology	80
	Maximum Likelihood Logistic Results	80
	Predicting and Sensitivity Analysis	89
	Tobit Analysis of Extent of Mechanization	92
	Earliness of Use	97
	A Problem with the Dependent Variable	97
	Overall Test of Significance	98
	Individual Variables	98

TABLE OF CONTENTS (Continued)

		Page
	Summary and Discussion of Results of the Multivariate Analyses	102
	Policy Issues and Implications	105
V	SUMMARY AND CONCLUSIONS	110
	Problem	110
	Objectives	111
	Data and Analytical Tools	111
	Results	113
	Suggestions for Further Research	116
GLOSSARY		117
APPENDICES		
A	AN ELABORATION OF THE ANALYTICAL METHODS	120
B	DATA COLLECTION AND PROCESSING	127
C	LISTS OF VILLAGES SURVEYED	135
D	GENERAL CHARACTERISTICS OF THE FARMER SAMPLE	139
E	BROKERS, WORKERS AND THE INSTITUTIONAL STRUCTURE	169
LITERATURE CITED		196
ADDITIONAL REFERENCES		204
BIOGRAPHICAL SKETCH		205

LIST OF TABLES

Table		Page
1	Indexes of areas harvested, yields and grain production for wet, hill and off-season paddy in peninsular Malaysia, 1970-75	10
2	Distribution of paddy land in peninsular Malaysia, 1974-75, by state	13
3	Cropping intensity index for paddy cultivation in peninsular Malaysia during the 1974-75 season, by states	15
4	Hypotheses with respect to signs of the independent variables	61
5	Distribution of strata	70
6	Distribution of sample by locality	72
7	Distribution of farmers in the Phase II survey by locality	74
8	Distribution of labor sample by locality	75
9	Characteristics of sampled localities	78
10	Logistic relations for decisions to hire mechanical harvesting of paddy, Muda Scheme, 1977-78	81
11	Predicted probability of machine adoption by full-time "average" male farmers by locality, tenure group and membership in Farmers' Association, Muda Scheme, 1977-78	91
12	Estimated elasticity of probability of adoption with respect to farm size evaluated at the mean of farm size, Muda Scheme, 1977-78	93
13	Results of Tobit analysis of percentage of paddy land harvested mechanically, Muda Scheme, 1977-78 (dependent variable = PER)	94

LIST OF TABLES (Continued)

Table		Page
14	Results of Tobit analysis of actual area of paddy land harvested mechanically, Muda Scheme, 1977-78 (dependent variable = ARCOM)	96
15	Results of Tobit analysis of earliness of use of the combine harvester, Muda Scheme, 1977-78 (dependent variable = TIME)	99
16	Summary of results of multivariate analyses of diffusion of the combine harvester, Muda Scheme, 1977-78	103
A-1	Number and percentage of farms by size and locality	140
A-2	Tenure status of farmers by locality	141
A-3	Farm size by tenure status	142
A-4	Percentage distribution of farms by size and tenure	144
A-5	Distribution of farm size among users and non-users of the combine harvester, 1977-78	145
A-6	Number of previous seasons farmers have used combine harvester by farm size	147
A-7	Date of first use of combine harvester by farm size	148
A-8	Descriptive statistics of explanatory variables	150
A-9	Comparison of means of explanatory variables between users and nonusers	151
A-10	Farmers' perception of relative cost of combine harvesting compared with old methods	154
A-11	Perception of grain loss by users and nonusers	156
A-12	Cross-tabulation of combine users and nonusers by neighboring users and nonusers	158
A-13	Percentage distribution of farmers by age within locality	160

LIST OF TABLES (Continued)

Table		Page
A-14	Reasons given by machine users for using combine harvester by locality	162
A-15	Reasons given by nonusers for not mechanizing harvesting by locality	163
A-16	Reasons for not mechanizing the entire crop by users	165
A-17	Average yields reported by users and nonusers of combine harvester by locality	166
A-18	Method of contacting machine operator by users	170
A-19	Distance to nearest broker from farmer's house	171
A-20	Distribution of brokers by ethnic group of principal and locality	172
A-21	Duties of broker	174
A-22	Social characteristics of brokers	176
A-23	Other socio-economic characteristics of brokers	177
A-24	Number and percentage of brokers reporting intention of buying a combine, by locality	178
A-25	Age of paddy farm workers by sex	181
A-26	Age of farm workers by marital status	182
A-27	Relationship of workers to head of household by locality	183
A-28	Number of working days, by worker type	184
A-29	Mean earnings from harvesting by worker type	186
A-30	Mean earnings from harvesting by age group	187
A-31	Mean earnings from harvesting, by sex of worker	188
A-32	Results of regression analysis of labor participation	191

LIST OF FIGURES

Figure		Page
1	Paddy growing areas in peninsular Malaysia	12
2	General plan of the Muda Scheme	17
3	A hypothetical technical change	23
4	Types of technical change	25
5	Map of Muda showing FDA locations and boundaries	71

Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

CHOICE OF TECHNOLOGY IN RICE HARVESTING IN THE MUDA IRRIGATION SCHEME, MALAYSIA

By

Ahmad Mahdzan Bin Ayob

March, 1980

Chairman: W. W. McPherson
Major Department: Food and Resource Economics

The focus of the present study is on the advent of the combine harvester, a highly capital-intensive technology, in the Muda Irrigation Scheme of Malaysia, a paddy growing area characterized by small farm size and fragmentation of land holdings. Plans call for farmers in the area to produce two crops of paddy annually. Thus, the harvesting period has been shortened. The primary purpose of the research was to identify and measure factors that have affected the adoption and extent of the use of this new technology by the farmers in Muda.

Primary data obtained by means of personal interviews with 858 paddy farmers were used in the investigation. The two major analytical tools employed were maximum-likelihood logistic regression to analyze the decision to use the harvester by farmers (treated as a binary dependent variable) and Tobit analysis to explain the level and earliness of use of the harvester. The dependent variable in earliness of use was the number of seasons the farmer had used the combine. Two equations were estimated for the extent of use, one with the actual area harvested by machine as the dependent variable and another one with the machine harvested area as a percent of total area as the dependent

variable. The Tobit model was deemed the most appropriate for the level and earliness investigations because the dependent variables in these cases were truncated at zero for over 70 percent of the respondents.

Parameter estimates for both models were obtained by maximum-likelihood procedures. Variables postulated to influence the dependent variables included farm size, tenancy status, full-time or part-time status of farm operator, degree of fragmentation, schooling, age, sex of farm operator, labor availability, membership in Farmers' Association, perception of economic and technical superiority of the new technology vis-a-vis the old, an indication of the machine's availability and location.

The study also described the institutional arrangements that have emerged to cater to the new technology and the welfare implications.

The results of the multivariate analyses showed that larger farms were more likely to use the machine, used it earlier and more extensively than smaller farms. Perceptions of economic and technical superiority of the machine were significant in influencing the probability, earliness and extent of mechanization, except that the way farmers perceived recovery rate was insignificant in the actual-area-combined equation. Machine use also appeared to be influenced by its availability in the neighborhood. The full-time farmer was more innovative than the part-time farmer, other things equal. The Farmers' Association member was also more inclined toward mechanization vis-a-vis the nonmember, ceteris paribus. Tenure status was inconsequential in the adoption of this technology; so were fragmentation, sex, age, labor availability and schooling--these did not contribute toward explaining the dependent variables.

The new technology has spread fast through the contractual system which made use of commission agents, a small number of progressive farmers who took advantage of an opportunity to improve their incomes. Machine use was further encouraged by a government which was sympathetic with the free enterprise system. It is believed that any displacement of labor caused by the machine resulted only in temporary "dislocation" as only about one-fifth of the land in Muda was mechanized. Since fragmentation of land holdings, age, education, sex and tenure did not appear to reduce the likelihood of using the machine harvesters and there was no evidence of the creation of serious unemployment problems, the incidence and extent of use of the machine harvester are expected to continue to increase.

CHAPTER I
INTRODUCTION

> Mechanization does not take place in a vacuum. It profoundly influences all aspects of life. Its very existence gives and will continue to give rise to numerous problems of social, economic and political magnitude. This is very true with most countries of this region where traditional agriculture is characterized by small farm holdings, low farm income and cheap labor.[1]

The Problem

Economists generally agree that "a dynamic contribution to economic development from the agricultural sector and significant improvement in rural welfare depend upon the modernization of agriculture through technological change" (Mellor, 1966:223). In the less developed countries, the mid-sixties and the decade of the seventies represent an era of unprecedented development and diffusion of new agricultural technologies in the form of high-yielding cereal varieties (HYV's), primarily wheat and rice. The term "green revolution" generally refers to this spread of the HYV's in various parts of Asia and other third world regions.

The introduction of irrigation facilities in many parts of Asia has enabled a greater intensity of the use of land through the practice of multiple-cropping with the HYV's. The higher yields with the new

---

[1]The late Prime Minister of Malaysia, Allah-yarham Tun Hj. Abdul Razak Hussein, in an opening address at a seminar on Experience in Farm Mechanization in South East Asia (Nov. 27-Dec. 2, 1972) held in Penang, Malaysia.

cereal varieties have typically been achieved by the simultaneous application of a package of other inputs. These include heavier applications of fertilizer, more effective control of weeds, insects and diseases and better management of water delivery and use (Ruttan and Binswanger, 1978:361). In many areas, the introduction of double-cropping with the new HYV's has been associated with intensified mechanization.

This dissertation is concerned with the diffusion of the service of the combine harvester, a form of capital-intensive technology, in smallholding (peasant) agriculture in Malaysia. The combine harvester is a relative newcomer in peasant paddy production compared with the tractor. At present the use of the harvester is primarily confined to the double-cropping area of the Muda Irrigation Project in the Kedah Plain--better known as the rice bowl of Malaysia.

The arrival of the combine harvester in the Muda Project area, primarily smallholding agriculture, is interesting in itself. To the novice in the Malaysian rice economy, the appearance of the combine harvester in the Muda area portrays a picture of what Mellor calls a "technologically dynamic agriculture"--an agriculture that is characterized by high capital investment. According to Mellor, "Normally this phase occurs after the process of economic development has been underway for some time . . . [and] describes the agriculture of North America, much of Western Europe and most other high income countries" (1966:226).

The presence of the combine harvester in Muda appears to be a classic example of a direct transfer (Evenson and Binswanger, 1978:166) of a mechanical capital-intensive technology from the developed economies to a developing country. Under this kind of technology

transfer, a country simply screens and adopts the best technology without modifying such technology through adaptive research of its own, unlike the diffusion of the biological technology in the form of the HYV's.

The introduction of mechanization into the agriculture of the LDC's has generated a debate among economists and engineers which revolves around the question of whether government should encourage or discourage the increased mechanization of agriculture as part of its policy of agricultural development (Gemmill and Eicher, 1973). The advocates of mechanization (the agricultural engineers and implementers of projects) emphasize the technical efficiency of greater mechanization and the augmented income arising therefrom (the land-owning class). Those who caution against too rapid a mechanization (supposedly, the economists and social scientists) are concerned with the possible displacement of labor and its attendant problems of rural unemployment, rural-urban migration and eventually urban unemployment. The theoretical argument for this contention is that with land and output held constant, an increase in the use of capital will necessarily reduce the labor input (Merrill, 1975:15). However, an opposite argument that mechanization in fact increases employment is premised on the notion that, following mechanization, off-farm employment can be created in the machine manufacturing and servicing industries (Falcon, 1967).

The adoption of the rice combine harvester in the Muda area poses several interesting questions which the present study intends to answer. As is true with most other forms of new technology, the diffusion of the use of the combine harvester among the small rice farmers is not uniform over time and space and across individual farmers. Some of the

farmers are early adopters, some are late adopters while a third group are nonadopters. What are the major elements that have contributed to the spread of this new imported technology among small farmers, the majority of whom have neither the financial nor the technical ability to own the machines? Can a meaningful pattern be discerned of this diffusion process over time and across farms in the study area? What institutional arrangement has emerged to cater to the spread of this technology? Who are the possible gainers and losers as a result of the innovation and what is the probable impact of harvesting mechanization on income and welfare of these groups of people?

Objectives

The overall objective of this study is to explain the incidence, impact, costs and benefits of the rice combine harvester in the Muda scheme.

Specifically, the objectives are as follows:

1. To identify and measure the relative contributions of the factors that are associated with farmers' decisions to adopt mechanical harvesting technology in the Muda scheme;

2. To relate the level of demand for the service of mechanical harvesting to farm and farmer characteristics;

3. To explain the pattern of the diffusion of the combine harvester over time;

4. To provide basic information on the institutional arrangements that have emerged to cater to and support the new technology;

5. To identify and characterize the gainers and losers as a result of this technical change; and

6. To examine current policies that affect mechanical harvesting and assess the degree to which these policies encourage labor displacement without significant productivity gains.

Importance

The combine harvester is a new phenomenon in Malaysian paddy production. However, its use by farmers appears to be spreading fast not only within the Muda area but also to other rice areas in the country. A knowledge of the determinants of this diffusion process is of interest to several groups of people--the students of technical change, government officials, policy makers and project implementers, as well as engineers and machine manufacturers and distributors.

Since its recent appearance in Malaysia, only one economic study (an undergraduate exercise) of the combine harvester has been done. The study examined the contractual system and calculated the private costs and benefits of the machine (Rayarappan, 1979).

Policy makers, such as those in the Muda authority who would be more concerned with the socio-economic consequences of the machine, may want to make forecasts of the rate and direction of the adoption of the machine for purposes of planning. A question that comes to mind is whether 100 percent mechanization of the harvesting operation is inevitable, given the present state of the arts. What are the consequences in terms of labor employment in the area? Cognizance of the factors affecting the diffusion of a technology in the mind of the concerned policy maker may enable him to control the rate of diffusion of the practice so as to minimize consequences that are deemed undesirable by society.

Engineers, as creators of the mechanical technology, should be interested in knowing the degree of acceptance and speed of the diffusion of their creation. At the same time, they should be interested in learning some of the economic and technological problems faced by potential adopters of their invention. Improvements to existing equipment call for specific information from the ground level.

The results of this study are expected to interest the manufacturers and dealers of the combine harvester. A rise or decline in its adoption is crucial to their economic interests.

Sources of Data and Analytical Tools

Sources of Data

The bulk of the data used in this study was obtained by means of a series of field interviews with farmers, combine harvester brokers (or commission agents), farm workers, combine distributors and government officials.

Five sets of structured questionnaires were used in the data collection. While the details of the sampling procedures are presented in Chapter III of this study, it may be pertinent to mention at this point that a total of 858 farmers (293 of them again on a second round), 315 farm workers, 38 machine owners and 59 machine brokers were interviewed. The survey work was conducted in three phases: Phase I was the survey of the 858 farmers; Phase II was the second round interview of 293 of the farmers and visits to the machine owners; and in Phase III, information from the 315 farm workers and the 59 machine brokers was solicited.

Phase I was carried out during the period October 27-November 15, 1978; Phase II during January 17-27, 1979; and Phase III during April 14-28, 1979--a total of 43 days in the field.

A minor source of data was published reports and other documents of government departments and agencies.

Analytical Tools

Both descriptive and analytical techniques were used, with the former setting forth the background and the institutional arrangements that have emerged to support the new technology. Statistical techniques served as the tools for testing the hypotheses formulated in Chapter III. The statistical techniques used included the simple univariate (frequency tables), bivariate (cross-tabulations with chi-square tests) and two multivariate analyses, namely the logit and Tobit analyses. The details of these techniques are explained in Chapter III.

The Malaysian Setting

Agriculture

Since achieving her political independence in 1957, Malaysia has had five 5-year development plans--the first two under the Federation of Malaya and the last three under Malaysia.[2] Foremost in all these development plans is the redress of rural poverty through the

[2]Malaysia was formed in 1963 with the inclusion of Sabah and Sarawak in a bigger federation with the former Federation of Malaya. Because time series data for Sabah and Sarawak are not as complete as for peninsular Malaysia and also because of the fact that time series are collected independently of one another, the discussion that follows is confined to peninsular Malaysia only.

modernization of agriculture. For example, in the Third Malaysia Plan (TMP, 1976-80), agriculture and rural development received the biggest share (25.5 percent) of the development budget (TMP:240). The high priority accorded to agriculture reflects the fact that it is the leading sector in the Malaysian economy in at least three dimensions--its contribution to the gross domestic product, to employment and to foreign exchange earnings. In 1978 agricultural output accounted for 29 percent of the GDP at factor cost, employed 44 percent of the work force[3] and contributed 46.5 percent of the value of total exports of the country.

The Third Malaysia Plan estimated the population would grow at the rate of 2.7 percent per annum during the TMP period, from 12.25 million in 1975 to 13.98 million in 1980 (TMP:145). This rate of projected growth in population is somewhat high compared with the majority of Malaysia's neighbors such as Singapore (1.4 percent), Indonesia (2.4 percent), Japan (1.3 percent), South Korea (1.6 percent), Philippines (2.3 percent) and Taiwan (2.2 percent) (FEER, 1978). On the other hand, Malaysia's rate of population growth is on a par with Thailand's (2.7 percent) and lower than Pakistan's (3.0 percent) and Vietnam's (3.0 percent). The racial composition of the Malaysian population is as

---

[3]Similar figures (percent of actively employed population engaged in agriculture) for some of Malaysia's neighbors are

	Percent
Thailand	71.8
Indonesia	62.0
Philippines	53.5
South Korea	44.6
Taiwan	29.1
Japan	12.2
New Zealand	12.0
Singapore	2.3

SOURCE: Far Eastern Economic Review, Year Book 1978.

follows: Malays, 53.3 percent; Chinese, 35.3 percent; Indians, 10.6 percent; and others, 0.8 percent.

The TMP estimates the labor force growth at 3.3 percent per annum, which adds some 748,000 new job seekers to the labor market during the Plan period. Employment growth in the agricultural sector is estimated to be 1.3 percent per annum. The TMP anticipates new land development to account for the major part of job creation in this sector. Employment growth rate was expected to be highest (5.9 percent per annum) in the oil-palm subsector, while the rubber subsector was expected to show an employment growth rate of only 1.6 percent. It is interesting to note that the government did not expect the employment bases of the rice, coconut and fishing industries to expand and all investments in these industries were geared to increase income levels of the presently employed only (TMP:152).

Paddy Subsector

Rice (paddy) ranks as the third most important crop in Malaysia, after rubber and oil-palm, in terms of acreage. In peninsular Malaysia, it accounted for about 12 percent (943,690 acres) of the total cropped land area in 1975. Slightly over 20 percent of the working population are involved in paddy production. More Malaysian farmers cultivate paddy than any other crop, with 55 percent of the country's 537,000 small holdings having wet (or flooded field) paddy (Taylor et al., 1979).

The salient features of paddy production in peninsular Malaysia for the period between 1970 and 1975 are given in Table 1. The harvested area for wet (flooded field) paddy was quite stable during

Table 1. Indexes of areas harvested, yields and grain production for wet, hill and off-season paddy in peninsular Malaysia, 1970-75

Season	Wet			Hill			Off-season		
	Area	Yield	Production	Area	Yield	Production	Area	Yield	Production
	Index[a]								
1970-71	100[b]	100[c]	100[d]	5	47	3	45	117	50
1971-72	98	95	92	4	48	2	56	114	61
1972-73	102	103	102	3	51	1	59	118	67
1973-74	100	108	108	2	51	1	61	121	70
1974-75	103	103	101	3	51	1	59	118	67

[a] The indexes used are based on wet paddy figures for 1970-71 season as a base of 100.

[b] Harvested area for 1970-71 was 875,740 acres.

[c] Yield for 1970-71 was 2,425 lbs. per acre.

[d] Grain production for 1970-71 was 649,000 long tons (1 LT = 2,240 lbs.).

SOURCE: Calculated from Ministry of Agriculture Malaysia, Statistical Digest, 1975:182.

the period, while off-season crop area harvested increased by more than 30 percent. This implies the expansion of paddy land put under double-cropping and, hence, an expansion of irrigation facilities. Based on the figures in Table 1, the area double-cropped in 1975 was about 57 percent of the wet paddy area for the same year, i.e., 59/103 = 0.57. The yield of wet paddy appears to have remained unchanged, around the 2,425 lbs. per acre for the base year, although the 1973-74 wet season registered the highest yield achieved during the period. The yield of off-season paddy was substantially higher than for the wet or main season paddy. Taylor et al. (1979) estimated the compound rate of growth of yield for the off-season to be around 1.8 percent compared with 1 percent for the main season crop of the same period.

Paddy cultivation is entirely a smallholding crop (Ooi, 1963:224), and over 95 percent of the total working population engaged in paddy farming are Malays. The main paddy areas are found in the northern part of the peninsula, north of latitude 4°30'N (Ooi, 1963:231). In 1975, 32 percent of the paddy land was accounted for by the Kedah Plain, while the Kelantan Delta in the northeastern sector accounted for another 19 percent of the total paddy area in the peninsula (Figure 1). Table 2 shows the distribution of paddy land by states in peninsular Malaysia. The five northern states of Perlis, Kedah, Penang, Perak and Kelantan account for over 75 percent of the paddy land in the peninsula, based on the main season crop of 1974-75.

For the off-season crop, the five northern states accounted for 87.17 percent of the total acreage planted. The states of Kedah, Penang, Selangor and Negri Sembilan show a noticeable increase in their shares of the total acreage for the off-season crop. This is consistent

SOURCE: Wong (1971:52)

Figure 1. Paddy growing areas in peninsular Malaysia

Table 2. Distribution of paddy land in peninsular Malaysia, 1974-75, by state

State	Main season		Off-season	
	Acres	Percent	Acres	Percent
Perlis	65,630	7.14	33,000	6.26
Kedah	293,270	31.89	226,880	43.06
Penang	38,000	4.13	39,980	7.59
Perak	119,750	13.02	60,350	11.45
Kelantan	173,550	18.87	67,500	12.81
Trengganu	28,813	3.13	16,620	3.15
Pahang	49,270	5.36	4,270	0.81
Selangor	50,510	5.49	49,600	9.41
Melaka	27,910	3.03	6,630	1.26
Johor	9,030	0.98	5,160	0.98
Negri Sembilan	18,800	2.04	16,910	3.21
Total	919,710	100.00	526,900	100.00

SOURCE: Ministry of Agriculture Malaysia. Statistical Digest, 1975: 187.

with the fact that the biggest irrigation scheme for paddy double-cropping in Malaysia is located in Kedah, while paddy has been double-cropped in Penang, Selangor and Negri Sembilan for some time--in fact, much earlier than the establishment of the Muda scheme in Kedah. States that appear to be losing their shares of the total acreage in the off-season crop include Perlis, Perak, Kelantan, Pahang and Melaka. Of these five states, Pahang registered the biggest reduction in its share of the double-cropping area, i.e., from 5.36 percent to a mere 0.81 percent. The remaining two states of Johor and Trengganu show no noticeable change in their respective shares.

Table 3 shows the area change and the cropping intensity index for paddy for the 11 states of peninsular Malaysia during the 1975 cropping season. It is interesting to note that although Penang, Selangor and Negri Sembilan are only minor paddy producing states, these states have achieved very high cropping intensities--205 percent for Penang, 198 percent for Selangor and 190 percent for Negri Sembilan. What this means is that these states have been able to double-crop all or almost all of their paddy land. States that have achieved a cropping intensity above the peninsular average (157.29 percent) include Kedah (177 percent), Penang (205 percent), Selangor (198 percent) and Negri Sembilan (190 percent).

Double-cropping

Double-cropping in Malaysia was started during the Japanese occupation in 1942-45 (Van, 1966:132) for the purpose of producing a greater proportion of the total rice needs of the country. In 1955 the government announced self-sufficiency as one of the goals of rice production.

Table 3. Cropping intensity index for paddy cultivation in peninsular Malaysia during the 1974-75 season, by states

State	Change in area share of off-season	Cropping intensity[a]
		Percent
Perlis	-	150.28
Kedah	+	177.36
Penang	+	205.21
Perak	-	150.40
Kelantan	-	138.89
Trengganu	0	157.68
Pahang	-	108.67
Selangor	+	198.20
Melaka	-	123.75
Johor	0	157.14
Negri Sembilan	+	189.95
Peninsula	0	157.29

[a] Cropping Intensity Index = $\left(\frac{\text{Off-season}}{\text{Main season}} + 1 \right) \times 100$.

SOURCE: Calculated from Ministry of Agriculture Malaysia, Statistical Digest, 1975.

Although the announcement became an annual occurrence, it was "not taken very seriously" (Doering, 1973:80).

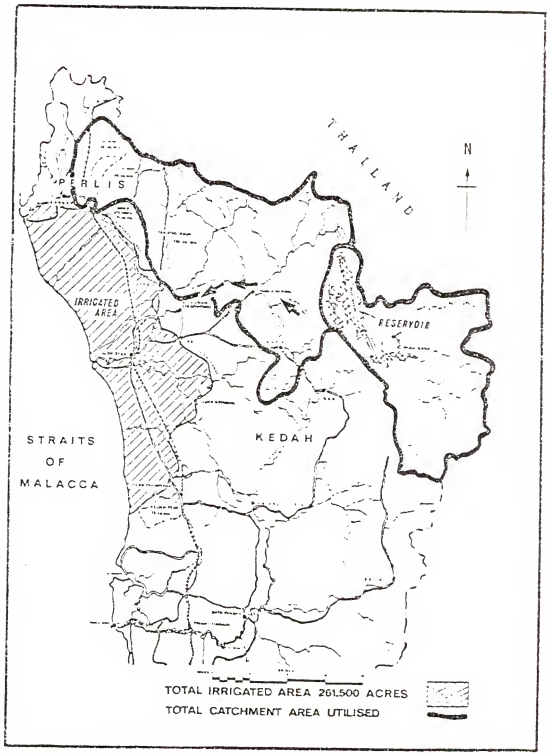
The means to achieving the self-sufficiency goal (and later, raising productivity and income of farmers) is naturally double-cropping with improved short-term, high-yielding varieties of paddy. The prerequisite to double-cropping is water availability and its efficient management. This means that irrigation facilities have to be planned and implemented in the traditional rice areas. The more recent and important are the Muda, Kemubu and Besut schemes, with the Muda scheme the largest in terms of geographical area covered and development expenditure.

The Muda Irrigation Scheme

History and development. The Muda scheme lies in a flat alluvial plain, about 14 miles wide and 46 miles long between the foothills of the Central Range in Kedah and the Straits of Malacca. The scheme stretches from south Perlis in the north to the foot of Kedah Peak (Gunung Jerai) in the Yan District in the south (Figure 2).

Partly financed by a M$135 million World Bank loan,[4] the Muda scheme was undertaken between 1966 and 1970 in order to enable double-cropping of 260,000 acres of paddy land (MADA, 1970c:1), over 28 percent of the paddy land in peninsular Malaysia. The project has long been a single crop paddy farming area which forms the major source of livelihood and employment for about 50,000 farm families. Indirectly, paddy farming in the Muda area provides income and employment for thousands of

[4]The current rate of exchange gives: U.S.$1.00 = M$2.20.



SOURCE: MADA (1970c)

Figure 2. General plan of the Muda Scheme

additional persons involved in the input supply industries, village stores, rice millers, mechanics, paddy traders and others. The total farm population of the scheme was estimated at around 325,000 people (MADA, 1970c:1).

The engineering design[5] of the Muda irrigation project entails the construction of two reinforced concrete dams in the mountains about 30 miles east of the project area. Across the Muda River, a concrete buttress dam 105 feet high was constructed to form a reservoir with a surface area of 10 square miles. Across the Pedu River, a 200-foot high, rock-filled dam was built to impound water with a surface area of 25 square miles. A 4.5-mile tunnel connects the two reservoirs to bring the water from the Muda to the Pedu reservoir. From here the water is released down the existing Pedu River channel to reach the project area where it is then diverted into the main canal.

The 61-mile long main canal carries the water through the entire length of the scheme area. An intricate system of branch canals and tributaries 564 miles long emanates from this canal and supplies irrigation water to the fields. Drainage is effected by a system of main drains and smaller drains about 560 miles in length.

Project implementation. To implement double-cropping in the Muda scheme, the Malaysian government in 1970 established the Muda Agricultural Development Authority (MADA) under the umbrella of the Ministry of Agriculture. The Authority is charged by legislation to plan and implement agricultural programs on a regional basis. MADA, in fact,

---

[5]The engineering aspects discussed here are taken from MADA (1970c: 2).

coordinates the activities of several other agencies connected with agriculture.

The Department of Agriculture at first was responsible for research, later taken over by the Malaysian Agricultural Research and Development Institute (MARDI), agricultural extension, education and farm mechanization training.

The entire Muda area is divided into four irrigation districts--one in Perlis and the remaining three in Kedah state. The districts are further subdivided into Farmer Development Areas (FDAs); there are 27 of these FDAs at present. Each FDA has a Farmers' Association through which modern agricultural practices, credit, inputs and marketing services are channeled to the farmers. Training in farm mechanization is done at the Farm Mechanization Training Center situated at Alor Setar, the capital of Kedah state (Mohamed, 1974:22-30).

Each FDA is organized into several small agricultural units (SAUs) and each unit is headed by a unit leader elected from among the progressive farmers. The pattern of organization that has emerged in the Muda area is in consonance with the recommendation of Arthur T. Mosher in his famous book, Creating a Progressive Rural Structure to Serve Agriculture. The FDA in Muda is, in fact, a "farming locality" in Mosher's terminology (Mosher,1969:3-4). On the average, there are about 2,000 farm households in a locality which is served by a Farmers' Association.

Other government agencies that are involved in the modernization program of Muda include the Federal Agricultural Marketing Authority (FAMA), the Agricultural Bank of Malaysia and the National Paddy and Rice Authority (NPRA), which later took over most of the functions of

FAMA in connection with rice marketing. NPRA is currently operating several paddy drying facilities throughout the region, and automation is the order of the day in all these facilities. While providing for 28 percent of the paddy drying needs of the country (Mid-Term Review, TMP, 1979:136), the Authority also regulates and supervises the marketing of paddy in the scheme, as it does throughout the country. The Agricultural Bank supplies the credit needs of the farmers as double-cropping means more purchased inputs. During 1976-78, the Bank approved loans amounting to M$198 million, of which M$88.6 million, or 44.8 percent, were for paddy production (Mid-Term Review, TMP, 1979:134). This makes paddy the biggest recipient of the Bank's loans.

Plan of the Dissertation

In Chapter II the literature relevant to this study is reviewed. This review takes off from the theoretical literature on technical change, pinpoints the difficulty of using the theory to solve the present problem and then highlights the empirical literature on technology diffusion. The chapter closes with a review of the empirical research on mechanization.

Chapter III discusses the methodology adopted in this research. First, the inclusion of the ex-ante independent variables is justified and hypotheses regarding these variables are postulated. Next, the choice of the estimation techniques is described and defended. The sampling procedure is then described. Finally, some salient characteristics of the sampled localities are discussed.

Chapter IV reports and interprets the results of the logistic and Tobit analyses.

Finally, Chapter V gives a summary of the study and then concludes the report by suggesting several areas for further research.

CHAPTER II
LITERATURE REVIEW

The purpose of this chapter is to review the theoretical literature on technological change as well as relevant empirical studies conducted in the field of technology diffusion. The review of the theoretical literature may enable the reader to place the present study in perspective, while a review of the related studies may be important in suggesting the methodology and identifying the variables likely to influence the diffusion of technology considered in this study. The limitation of the theory and an attempt at its modification in regard to the present study are discussed.

Theory of Technical Change

Binswanger (1978:18) refers to the term technical change as "changes in techniques of production at the firm or industry level that result both from research development and from learning by doing." He continues:

> The term technological change will be used to refer to the result of the application of new knowledge of scientific, engineering, or agronomic principles to techniques of production across a broad spectrum of economic activity. We specifically exclude from the definition of technical change those shifts in individual factor productivities that result in choices among known techniques or from changes in commodity mix brought about by changes in the relative prices of factors or products. (1978:19)

A technical change may be represented by any inward movement of the unit isoquant over time (Figure 3). This inward movement of the

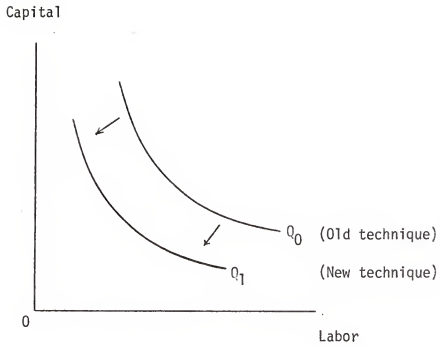


Figure 3. A hypothetical technical change

unit isoquant is equivalent to the emergence of a new, more efficient production function.

Following Hicks (1932), Fellner (1961), and Ahmad (1966), one may classify a technical change as labor-saving, capital-saving, or neutral according to whether, at the prevailing relative input prices, the optimal capital/labor ratio increases, decreases, or remains unchanged (Figure 4).

Following Binswanger (1978:20-23), the bias, B, in technical change may be written as follows:

$$B\Big|_{\text{relative factor prices}} = \frac{\partial(K/L)}{\partial t} \cdot \frac{1}{K/L} \gtrless 0 \rightarrow \begin{cases} \text{labor-saving} \\ \text{neutral} \\ \text{capital-saving} \end{cases}$$

When the old and the new technology exist side by side,[1] the bias of the new technology may be measured as

$$B = \frac{|\Delta L|}{L} - \frac{|\Delta K|}{K} \gtrless 0 \rightarrow \begin{cases} \text{labor-saving} \\ \text{neutral} \\ \text{capital-saving} \end{cases}$$

where ΔL is the difference in the amount of labor per unit of output between the new technology process and the old technology process, ΔK being similarly defined for capital, L is the average labor use per unit of output between the new technology process and the old technology process, and K is similarly defined for capital.

The proportional change in the labor input to produce a unit of output is

---

[1] This can happen because of imperfect knowledge and/or capital scarcity. The problem of studying the adoption and diffusion of a new technology implicitly assumes the coexistence of the new with the old technology.

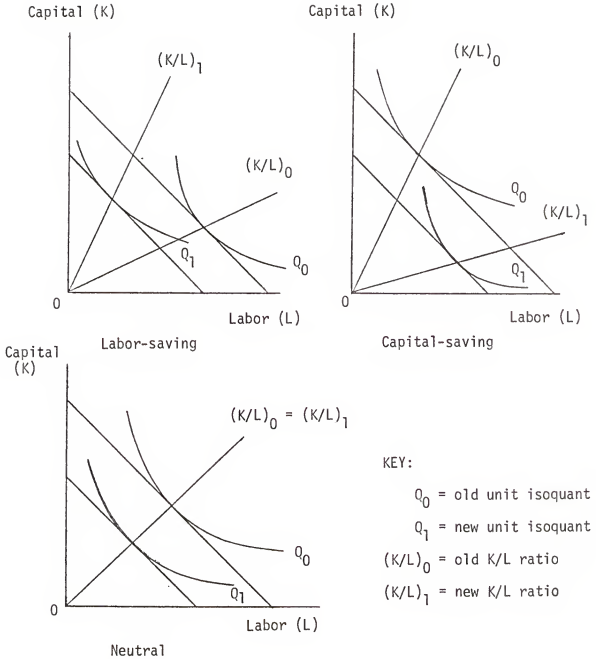


Figure 4. Types of technical change

$$\frac{\Delta L}{L} = \frac{L_0 - L_1}{(L_0 + L_1)/2}$$

and similarly for capital

$$\frac{\Delta K}{K} = \frac{K_0 - K_1}{(K_0 + K_1)/2}$$

Basically, the theory of induced innovation--a term coined by Hicks (1932)--postulates that changes in factor prices induce biases which save the progressively more expensive factors, although Hicks himself did not specify the mechanism by which this would take place (Binswanger, 1978:23).

Many economic theorists after Hicks wrote and debated on the theory of induced innovation--some for and others against it. Among them are Rothschild (1954), Salter (1960), Fellner (1961), Kennedy (1966), Blaug (1963), and Ahmad (1966).

Those authors who are strongly against the theory of induced innovation (e.g., Salter, 1960; Blaug, 1963) argue that when labor costs rise, any new production technique that reduces total cost is welcome regardless of whether that new technique saves labor or capital. Summarizing these critisms, Ahmad (1966:345-346) writes

> We only have to remind ourselves that the act of invention takes us from one production function to another, while factor-substitution is moving from one point to another of the same production function. Thus, whether there has been a change in factor prices or not, as long as we have moved from one production function to another, there has been an invention. This is . . . not to suggest that it is also easy in practice to distinguish between these two movements, but this kind of difficulty is not specific to the problem of induced invention . . . .

The theory of induced innovation seems to be cast within a framework of explaining the invention of a new technique or the creation of a new production function. Common to all the writings on induced innovation is the idea of "budget constraints and research costs" (Binswanger, 1974a:940-958). On the empirical side, one notices that most research work based on the theory of induced innovation has resorted to time series data pertaining to whole economies (e.g., Hayami and Ruttan, 1971) and cross-sectional data in which the unit of observation is a whole state (Binswanger, 1974a). In other words, these studies tend to focus on the aggregate behavior rather than on the individual innovator or producer. As it may be recalled, the present study is concerned with the diffusion of the combine harvester in the Muda Scheme in Malaysia. Although the theory of induced innovation is a useful starting point in considering the adoption of a new technology in smallholding agriculture, it has serious limitations to be conveniently applied in the present study. It should be remembered that the combine harvester is not an indigenous technology; it was developed in the West and then imported in toto into Malaysia. This study is not concerned with the factors that have brought about this importation, which shall be taken as given, but rather with the adoption of the machine by individual farmers at the farm level. Ruttan and Binswanger (1978:362) conceded that

> At present it seems more appropriate to analyze the mechanization of motive power in agriculture within the context of choice-of-technology model than within a framework of an induced innovation model.

They also observed that

> It is consistent with the available evidence to view the mechanization of land preparation and harvesting operations

> that is sometimes associated with the green revolution as responsive to changes in the relative prices of mechanical power, animal power, and labor rather than as a technical complement to the green revolution seed-fertilizer package. . . . [In Japan and Taiwan] mechanization was induced by a decrease in the rural labor force and by the rising wage rates for agricultural labor that were associated with growing demand for labor in the urban industrial sector. (1978:361-362)

Choice of Technology

The induced innovation hypothesis appears to offer little explanation to the decision by producers to shift from an optimal point on the old unit isoquant to an optimal point on the new unit isoquant (see Figure 4). On the adoption of new and profitable agricultural techniques, de Janvry states

> The adoption of new and profitable agricultural techniques--once they have been made available by private business firms or public research institutions or by importation from other countries--is determined essentially by the profit objectives of the individual farm entrepreneur. The rate at which new techniques are adopted is conditioned by a set of economic, institutional, and structural factors that tend to introduce severely regressive biases.(1978:312)

Although the induced innovation hypothesis has to be relegated to a minor role in favor of the choice-of-technology model in studying the adoption of a new technology by farm firms, this does not imply that the latter model is already well developed. A review of the theoretical literature failed to reveal any formally documented exposition of a so-called "theory of choice-of-technique" as mentioned by Ruttan and Binswanger (1978:362). However, the problem of innovation has also been a fertile area of research by rural sociologists and anthropologists for quite some time. Attention is now turned to these specialists. The work of Rogers and Shoemaker (1971) is now a classic in the field of

technology diffusion. The senior author first published this work in 1962 under the title of Diffusion of Innovations.

Rural sociologists view the adoption process as consisting of five phases: the awareness stage, the interest stage, the evaluation stage, the trial stage, and finally the adoption stage. Thus, the individual first "learns of the existence of a new idea," "develops an interest in it and seeks additional information," "makes mental application of the new idea to his present and anticipated future situation and decides whether or not to try it," "actually applies it on a small scale in order to determine its usefulness in his own situation," and finally "uses the new idea continuously on a full scale" (Rogers and Shoemaker, 1971:100-101).

Rogers and Shoemaker (1971:138) conceded that "It is the receiver's perception of the attributes of innovations, not the attributes as classified by experts or change agents, which affect their rate of adoption." They listed five attributes of innovation as follows (1971: 134):

(1) relative advantage,

(2) compatibility,

(3) complexity,

(4) trialability, and

(5) observability.

Relative advantage of an innovation may be emphasized by a crisis, such as the on-set of bad weather. For example, the fear of sudden heavy rain may render the combine harvester a better proposition than the traditional method of harvesting. Relative advantage can take several forms, namely, "the degree of economic profitability, low

initial cost, lower perceived risk, a decrease in discomfort, a saving in time and effort, and the immediacy of the reward" (Rogers and Shoemaker, 1971:139). Economic incentives such as those provided through government policy instruments are also important in determining the rate of adoption of innovations.

Rogers and Shoemaker (1971:145) define "compatability" as the "degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of the receivers"; "complexity" is defined (1971:154) as "the degree to which an innovation is perceived as relatively difficult to understand and use and any innovation may be categorized on the 'complexity-simplicity continuum.'" It should be obvious that the more complex an innovation the less is the probability of its adoption. "Trialability" is defined as "the degree to which an innovation may be experimented with on a limited basis, including a 'psychological trial'" (1971:155). The authors viewed "observability" as the "degree to which the results of an innovation are visible to others" (1971:155).

In explaining the rate of adoption, Rogers and Shoemaker further suggest the inclusion of other variables such as

(1) the type of innovation-decision,

(2) the nature of communication channels used to diffuse the innovation at various functions in the innovation-decision process,

(3) the nature of the social system, and

(4) the extent of change agents' promotion efforts in diffusing the innovation (1971:157).

They further suggest that adoption is related to adopter characteristics. The more important ones among these are demographic

and socioeconomic characteristics such as age, education and farm size.

Agricultural economists studying the diffusion of the new biological technologies (e.g., the HYV's) have added another group of variables under the physical environment--the topography and agroclimatic status of the environment in which the adopter lives. The review of the empirical literature in a later section will attest to this last statement.

Diffusion of Technology: The Empirical Literature

Rogers and Shoemaker (1971:50-59) report that, up to the middle of 1968, rural sociology had contributed 480 research publications (or 44.28 percent) on technology diffusion, which altogether number 1,084, thus making the discipline the leader in the field of diffusion research. Agricultural economics was lumped together with the "other traditions" category which includes general sociology, psychology, general economics, geography, industrial engineering, etc. These disciplines contributed a total of 227 publications or 20.94 percent. In the Bibliography section, Rogers and Shoemaker list 1,237 empirical research publications on the subject, but only 36 of these publications are classified as falling under agricultural economics. The classification is based on the disciplinary affiliation of the researcher (Rogers and Shoemaker, 1971:48).

The situation has certainly changed since that time. Recently there appears to be a flurry of research reports by agricultural economists on the diffusion of agricultural technology. The purpose of this section is to review some of these studies in order to gain a better

understanding of our present problem and pick up some useful methodology.

By reviewing only papers from this group of researchers does not mean that other disciplines have nothing to offer to the present study. On the contrary, these other disciplines, especially rural sociology and anthropology, appear to have permeated the writings on technology diffusion in all disciplines including agricultural economics. But, because of obvious limitations of time and space, only selected literature available in the writer's own discipline is reviewed.

Griliches' work (1957) on the diffusion of the hybrid maize in the United States is now well-known to the student of technical change--at least in the field of agricultural economics. Griliches pioneered diffusion research among agricultural economists and set the stage for the numerous diffusion research endeavors that came later.

In this study, Griliches explains the regional variation in the date of initial planting of hybrid corn in the United States by the size and density of the potential hybrid seed market, measured by the size of a region and its density of corn production.[2] Griliches hypothesizes that private seed companies and research stations would initiate work on hybrid corn in regions (states) where corn production was concentrated--meaning to say that innovativeness is a function of the potential rate of return to research investment. Griliches also explains the rate of adoption (percentage of farmers growing the hybrid corn in a region) and the level of acceptance of new technology in terms of the absolute profitability of the switch from open-pollinated to hybrid corn.

---

[2]Cited in Evenson and Binswanger (1978:165).

Since the unit of observation in Griliches' study is a state in the United States, variations in adoption among individual farmers are not explained. However, the representation of the diffusion of the hybrid corn over time as a sigmoid curve is of great value to the present undertaking. Griliches considers a 10 percent rate of adoption of the hybrid corn as a starting point in the diffusion of this biological technology. He then presents a series of sigmoid curves, one for each region, to show the cumulative percentage of adopters. From these graphs, one can distinguish the early adopters (states) from the late ones.

Ten years after Griliches' work, Hrabouszky and Moulik (1967) studied the profitability of using the Olpad thresher under farm conditions in Delhi Territory, India, and investigated the factors responsible for the differences in its adoption. Here, the researcher focussed on the diffusion of a mechanical technology at the micro or farm level and interviewed 32 adopters and 44 nonadopters. Psychometric tests were used to measure relevant psychological variables. The thresher was found to be profitable in all three alternative estimates of net returns, varying from a high-cost/low return conservative estimate to a low-cost/high return optimistic estimate.

Comparison of the two villages where the respondents lived showed greater similarity in most variables which were expected to influence adoption. However, the village where adoption was high offered a cooperative attitude toward the agricultural extension program and had viewed more demonstrations of the thresher by the extension agent. The village where adoption was low was faction-ridden and distrusted the extension personnel in the area. The authors emphasized that the study

supported the belief that useful, practical, and profitable improved implements need not have extensive subsidies and credit for their adoption once they have been successfully demonstrated. The authors noted the difficulty of quantifying the reduction in total threshing time which was said to be an important source of return (1967:5).

> This reduction in total threshing time gave advantages of reducing the risk of possible losses caused by pests, such as rats, birds, and pilferage, and also reduced the possibility of untimely rains creating a need for extra labor in drying, slower threshing and lowering the quality of the grain .... (Hrabouszky and Moulik, 1967:56)

The authors used the t-test to test the difference in the means of several variables between the adopters and nonadopters. The new technology studied by Hrabouszky and Moulik (1967) differs from the present study in terms of ownership. The combine harvester in Muda is owned by a "capitalist" class and contracted out to the ordinary farmers for a fee. The decision to use the machine means the decision to purchase its service which is divisible in nature just like chemical inputs. It differs from chemical inputs such as fertilizer in that government extension service does not, and is not required to, play an active role in influencing the use of the combine harvester (see also Chancellor, 1971:854) as it does with fertilizer and other agronomic practices.[3]

A review of additional studies on the diffusion of technology connected with the hybrid cereals in selected countries is presented next. Although these studies may not be directly relevant to a study on mechanization, the methodology adopted by the authors has great appeal

---

[3]The fact that the Muda Authority owns 30 units of the smaller type machine does not necessarily mean that it is actively persuading farmers to adopt the machinery. It appears that the Authority is concerned with providing some competition in order to keep the fees down.

in the present research on the diffusion of a new technology. Even though the form of the innovation may differ, the process of diffusion itself should be considered universal.

Cutie (1975) studied the diffusion of the hybrid corn technology in El Salvador. Three dependent variables were studied; namely, "use" of nitrogen (using at least half the recommended quantities), Y_1, adoption of hybrid seed, Y_2, and "adoption" of nitrogen, Y_3. The explanatory variables used were farm size (X_1), off-farm work (X_2), location of farm (X_3), distance to markets (X_4), credit use (X_5), extension contacts (X_6), farmer's age (X_7), and farmer's education (X_8). Cutie (1975) derived three sets of regression equations. The first set was for farmers who grew maize in solo stands; the second set related to farmers who grew maize interplanted with sorghum; and the third set was based on the pooled data, i.e., all maize growers. In this study, Y_2 and Y_3 were dichotomous dependent variables. Cutie recognized the inappropriateness of applying ordinary least squares in this case.

Cutie's (1975) final regression models contained from two to four explanatory variables, i.e., various combinations of the variables farm size, agro-climatic region, education, and credit. He obtained R-squares which ranged from 0.02 to 0.28. Farm size was statistically significant ($t > 2.0$) in the hybrid adoption as well as the nitrogen "use" and nitrogen "adoption" equations for the pooled data. The "agro-climatic region" was significant in all the models except in the hybrid adoption for farmers planting maize inter-cropped with sorghum.

Cutie (1975) recognized the modesty of his findings and reserved policy recommendations by only saying that

> while agro-climatic factors and farm size are influencing nitrogen use and the farmer is playing a strong role in the pattern of hybrid adoption, it appears that more credit and better access would promote the use of fertilizers while easier access to hybrids could speed their wider use. (Cutie, 1975:24)

Colmenares (1975) conducted a similar study in Colombia. Nitrogen use (continuous variable--kg/ha), hybrid seed (dichotomous) and fertilizer (dichomotous) were used as dependent variables. Topography, tenure, education, visits from technicians, yield variability index (risk), two zone dummies, farm size, nature of maize stand (pure or mixed) and credit use served as explanatory variables. Again, least squares linear regression was used to quantify the hypothesized relationship.

The regressions explained from 2.7 to 58.8 percent of the variations in the dependent variables. Farm size was statistically significant in most of the equations except for nitrogen use (kg/ha) in Zone 2. Education was significant only in the nitrogen use equation in Zone 1.

The regressions showed that extension visits had little or no effect on adoption, except when they occurred in conjunction with credit use (Colmenares, 1975:25-26). Farm size and farmer characteristics had the expected signs in the fertilizer and hybrid adoption, but in general each one alone explained very little of the variability in adoption levels among farms or among zones (1975:26). Education was found to affect the probability that a farmer would use hybrids. Farm size, although statistically significant, had only a small effect on hybrid adoption. Colmenares concluded that the ". . . evidence of important economies of scale in hybrid use is slight once other factors are considered" (1975:28). The other characteristic found to be important

in hybrid adoption was topography. Farmers in valleys were more likely to adopt than were farmers on hillsides.

For the fertilizer use model, visits by technicians did not have a significant effect on the dependent variable, while the use of credit was associated with an 80 percent greater probability that a farmer would be using fertilizer, and with an additional 35 kg/ha of nitrogen (Colmenares, 1975:29). Farm size was also shown to be a significant variable in the fertilizer use model. Each 10-hectare increase in size was associated with a 1 percent increase in the probability of fertilizer use and with the use of an additional 5 kg/ha of nitrogen (Colmenares, 1975:29).

Colmenares also found education and tenure to be significant in explaining nitrogen use (1975:29). Yield variability (proxy for perceived risk) was found to be slightly negatively associated with fertilizer use and farmers growing maize in pure stands were both more likely to be using fertilizer and used more fertilizer on the average.

Demir (1976) employed two multivariate techniques to analyze farm adoption of the new bread wheat technology in Turkey--namely, multiple regression analysis (OLS) and logit analysis. The dependent variables considered were hybrid adoption (dichotomous) and fertilizer use ($N + P_2O_5$) in kg/ha.

Demir (1976) used 17 independent variables to explain the two decision variables. These were classified under farmer characteristics, farm characteristics and government policy. The farmer characteristics included age, education, family size, membership in an agricultural society, radio listening, off-farm work, other income and weather risk (an index of farmer's assessment of weather risk). Farm characteristics

included farm size, percent of farm allocated to wheat, distance from field to home, ownership status, use of tractor and topography class. The government policy variables used were whether or not the farmer sold to the government agency, whether or not HYV seed was easy to obtain and whether or not the farmer had participated in field days, lectures or demonstrations.

Based on the logit analysis ($t > 1.0$), Demir (1976) found education to be an important factor in the adoption of the HYV wheat in all three regions studied. This variable had the expected positive sign and so did the family size variable although no explanation was given for the result. The risk variable was significant with the "correct" sign in two regions and insignificant with the "wrong" sign in the third. Membership in agricultural societies was not significant.

Of the six variables describing farm characteristics, Demir (1976) found tractor use and topography to be important only in one region with the anticipated positive sign. Distance to field was important in two regions but with different signs. Farm size was found to be important only in one region.

With the policy variables, Demir (1976) found wheat selling to be important in all three regions studies--those farmers who sold wheat were

> . . . estimated to be more likely to adopt HYV's by 9 percent in Thrace [suggesting] that any market discounts which might exist for HYV's do not adversely affect the decision to adopt, contrary to the inferences tentatively drawn . . . . (1976:22)

Mangahas (1970) studied the diffusion of the new rice varieties in Central Luzon, the Philippines, by explaining the farmer's decision to use or not to use a new rice variety. Since the dependent variable was

dichotomous in nature, linear probability functions were estimated. Seven independent variables were used to explain the adoption decision; namely, age, schooling, a measure of rice expertise (lagged one year), farm size, a dummy variable for owner-operatorship, the interest rate on borrowed funds and a dummy variable for pump irrigation.

With the sample of 866 farmers, Mangahas (1970) first classified the farmers into six groups based on the presence of irrigation, participation in the new extension program and (for the irrigated farms) whether or not the farmer planted a second rice crop in the dry season.

Mangahas (1970) found rice-expertise to be most important. This variable was measured by the proportion of seven recommended production practices (excluding use of new variety seed) which the farmer had adopted in the preceding crop year. The coefficients of the other included variables were generally of the expected signs although they were small compared with the rice expertise.

Gafsi (1976) employed multiple regression analysis to explain variations in the observed percentages of bread wheat area in HYV's and durum wheat area in HYV's in Tunisia. Twenty-one explanatory variables were used to explain the effect of adoption of the high-yielding varieties. Among these were farm size, potential family labor available, farming experience, years of schooling, years of experience with the HYV's, ownership of tractor, off-farm income, whether farmer reported any difficulty in getting the HYV (Yes = 1, No = 0), etc. The independent variables explained 89.4 percent of the variation in the first dependent variable (bread wheat) and 80.9 percent in the second dependent variable (durum wheat). Significant variables (at 5 percent level) in the bread-wheat equation were price ratio of ordinary wheat in

"tolerated market" to "legal market," yield of ordinary wheat, farm size, topography and farming experience. Topography contributed the most (0.82) to the R^2 obtained. In the durum wheat equation, the variables that were significant (5 and 10 percent) were access to credit, difficulty in getting seed, the price ratio variable, topography, distance to market and family claim on output.

Gerhart (1975) studied the diffusion of hybrid maize technology in Western Kenya. The variables to be explained were adoption of hybrid maize (defined as use of hybrid seeds for more than half the farmer's acreage), use of fertilizer and insecticide. Several analytical tools were used in analyzing the data which were collected from a sample of 361 farmers--namely, bivariate (with tests of difference between means, chi-square tests and Pearson correlation) and multivariate probit and regression analyses. Fourteen independent variables were included in the probit analysis, although not all at once. The five interval-scale variables used were age, education measured in years of schooling, farm size, distance to nearest source of input and an imputed value of cash crops per annum. The remainder were dummy variables, namely, agroclimatic zone, perception of risk, off-farm work experience, experience in commercial farming, whether or not the farmer was visited by an extension agent the previous year, attendance at maize demonstration and attendance at a farmer training center. Only the results of the probit analysis will be mentioned here. Gerhart found that the variables that significantly influenced the adoption of hybrid maize in Kenya were the agroclimatic zone, perception of risk, level of formal education, knowledge of credit availability and imputed value of cash crops. Zone, education, credit and cash crop were positively related to adoption

while risk was negatively related (Gerhart, 1975:32). Age was negatively related ($t = 1.61$) to adoption and farm size was positively related ($t = 0.05$) but only age was significant at the 0.10 level. Gerhart obtained pseudo-R^2 values of 0.75 and 0.76 and percents of cases correctly predicted were 91.5 percent and 91.9 percent, respectively.

Gerhart (1975) also studied the earliness of adoption in a multivariate framework. He used the year of adoption as the dependent variable and regressed it against farm size, agroclimatic zone, cash crop value, age, education and risk perception. Gerhart found the first three variables to be significant at the 0.10 level while the remaining ones were not.

The above studies on the diffusion of new technology may be summarized in the following words. The major focus of these studies was on biological technology, i.e., the spread of the new high-yielding cereal varieties of rice, wheat and maize. All authors used multivariate techniques (in addition to other techniques) in analyzing the adoption variable--a technique that considers all explanatory variables at the same time and allows the partial effect of one variable to be examined while holding all other variables constant. The technique used most often was the ordinary least squares (OLS) multiple regression, but the logit and probit techniques were also employed by some researchers.

Among the explanatory variables used in those studies, the more common ones included farm size, age, education and agroclimatic zone. Risk perception and experience in farming were used by one or two researchers.

All the studies were what might be called micro-level studies as they focused on the farm level. The locations of most of these studies were in the less developed countries where the new biological technologies have been spreading at a phenomenal rate often referred to as the "green revolution."

The present writer views the diffusion of the new mechanical paddy harvester in the Muda area as functionally similar to the diffusion of the new hybrid seed technology because the new mechanical technology is essentially divisible like the new chemical inputs associated with the HYV's. In Chapter III, several theoretical models of the diffusion of this new mechanical technology in smallholding agriculture are presented. The lessons learned from the literature review will form a major thrust in the formulation of models of the diffusion of the combine harvester in Muda. In the next section a number of studies on mechanization which may provide additional insight into, and perspective of, the problem at hand are reviewed.

Economics of Mechanization: The Empirical Literature

The literature on the economics of agricultural mechanization is quite voluminous. In what follows, an attempt is made to highlight only a few of the studies in this field, which have the most direct bearing on the present research endeavor.

Billings and Singh (1970) constructed a physical projection model for Punjab-Haryama. An attempt was made to determine the influence of technological changes in farm production on employment and income. They looked into the pattern of labor displacement, its possible rate and the

composition of displaced workers. It was estimated that, in Punjab, 32 million work days were saved in 1968 by mechanical threshers. The authors concluded that some casual laborers were undoubtedly affected and the need for hired staff somewhat diminished. Work days and total money wages declined. The study projected that the decline in labor demand will reduce wages from Rs. 10 to Rs. 4 or 5 per day. They also concluded that the operators of small farms (5 acres or less) will likely become casual laborers during peak periods to supplement their income, which meant that up to 40 percent of Punjab farmers might fall into this category. A further conclusion was that mechanization may increase farm incomes for all groups but disporportionately. The direct effects of mechanization, according to the authors, were

(1) the reduction of per unit cost of production as labor cost is reduced;

(2) as labor demand falls wages will fall, thereby benefiting the smaller farmers who need labor but cannot mechanize. The smallest of farmers will be hurt because they both sell and hire labor; and

(3) the larger farmers will gain as they have the opportunity and scale to make the best use of inputs.

Billings and Singh (1970) concluded that to dampen the development of a cheaper, more productive food producing sector simply to provide employment would not appear a viable alternative. They asserted that the agricultural sector cannot be a food-producing sector and one providing relief at the same time.[4]

---

[4]Binswanger argues that the conclusion is not entirely correct. "It all depends--if the output effect is small but the welfare effect is large, it is justified to tamper with agriculture" (Personal communication, August 3, 1978).

Inukai (1970) studied the pattern of diffusion of farm mechanization in Thailand. Utilizing census data, he examined the effects of mechanization on output and other inputs and on land productivity. A simple regression model was used to show the relationships. He concluded that selective mechanization might create more jobs than it eliminated.

Bose and Clark (1969) employed a cost-benefit analysis to appraise the desirability of mechanization in Pakistan. The cash flow indicated that mechanization is not socially advantageous, although it showed private profitability. Pakistani farmers found mechanization profitable because it eliminated bullocks, reduced farm labor requirement and it evicted tenants. According to the authors, if Pakistan were to mechanize at the rate of 12 percent per year (as recommended by some consultants) the direct cost (in 1975 figures) to society would be Rs. 330 million, and direct benefits Rs. 200 million--a net loss of Rs. 130 million to society.

Duff (1975) provided a conceptual model for assessing the impact of alternative development strategies on output and employment within agriculture. Combining macro data with cross-section (survey) data, he discussed and provided evidence of the impact of mechanization on output, employment and income in the Philippines. Duff concluded that mechanization has had only a limited positive effect on both output and employment. Since most of the labor and animal power that had been replaced by mechanization came from family sources, landless labor had not been adversely affected. Furthermore, much of the mechanization is of the cost-reducing nature and not output-increasing. Timeliness was considered important by farmers in increasing cropping intensity by

reducing the risk of late planting. This reduction in risk could increase output.

Gemmill and Eicher (1973) made an excellent review of studies on mechanization presented at a seminar at Michigan State University. Timmer (1972) made a cost-benefit study on the choice of milling facilities in Indonesia. Previously, an engineering firm made a financial cost/benefit analysis and recommended equipment costing U.S.$63.2 million and employing 7,300 people. Timmer's economic analysis recommended power-mills at a cost of U.S.$12.5 million and employing 14,700 people. Timmer's study demonstrates the importance of economic rather than merely financial analysis for decision making.

Donaldson and McInerny (1973) combined time-series with cross-section data to study the impact of tractors in Pakistan. They used the "before" and "after" approach in studying the impact of tractorization on farm size. They found that following mechanization, farm size had grown by 240 percent. This growth was by and large accomplished by the eviction of tenants.

Ahmad (1972) used linear programming to analyze the impact of mechanization on individual farms. By running the program with different levels of mechanization, an indication of changes in output, income and employment following mechanization was given. Ahmad found that the financial incentive to mechanize with tractors was very great if the farmer had a supplementary supply of water available. The assumption of the LP model is that a farmer maximizes profit subject to certain physical and institutional constraints. Risk aversion was not incorporated.

Thirsk (1972), using aggregate data, examined factors influencing the rate of mechanization in Colombia. A general equilibrium approach was used. The objective was to ascertain whether the Colombian government's policy of providing credit for mechanization at half the market rate of interest had increased the GNP and employment and whether the benefits of mechanization had accrued to the owners of land, labor or capital. The author estimated the elasticity of substitution between labor and capital in agriculture to be 1.4. From the simultaneous equation model which he constructed of Colombian agriculture, Thirsk concluded that the subsidization of mechanization had lowered GNP, favored the capital-owning segment of society and resulted in lower agricultural development.

Singh and Day (1972) used recursive LP to simulate the impact of new technology (including mechanization) in the Punjab for 1952-65 and made projections to 1980. They predicted that the absolute demand for labor would decline 10 percent between 1970 and 1980 because of mechanization and this would result in surplus labor. The rate of mechanization was shown to be insensitive to small changes in wage and interest rates; hence the potential influence of government policy was severely limited.

Gotsch (1972) compared the impact of mechanization in Pakistan with that in Bangladesh, concluding that in Pakistan the impact had been less equitable due to the different institutions there. In Bangladesh tractor-hire (divisible) had spread the benefits of mechanization whereas private ownership (indivisible) in Pakistan had led to eviction of tenants.

The study by Barker et al. (1974) attempted to examine the trends in mechanization and employment, to identify the relationships between

the seed-fertilizer technology, mechanization and employment and to examine current government policies that affect mechanization. Cross-sectional data were used. They observed that any effort to mechanize threshing in Laguna would probably meet with stiff resistance from hired laborers, most of whom were landless and depended heavily on transplanting, harvesting and threshing jobs for their income. As few of these landless laborers were involved in land preparation, there appeared to be less resistence to this task. As a result of mechanization, labor requirements for land preparation dropped from 27 to 15 percent of the total while labor requirements for weeding increased from 8 to 17 percent.

Tsuchiya (1971) tested the hypothesis of economic rationality in the Tohoku district of Japan where the largest spread of power tillers was observed. Central to the study was the assumption that farmers maximized utility subject to the production function (isoquant) and a money equation. The arguments in the utility function were wage rate of hired worker (A) and family labor input in farm and nonfarm sector (m). Tsuchiya concluded that farmers were rational in their decision to mechanize in that they were minimizing costs subject to a given output.

Schmitz and Seckler (1970) studied the impact of the tomato harvester on labor demand. They also calculated the social benefits and costs of the adoption of the tomato harvester. Gross social returns to aggregate research and development expenditures were close to 1,000 percent. They contended that even if displaced labor had been compensated for wage loss, net social returns were still highly favorable. Since tomato pickers were unorganized, no compensation was demanded or paid. Their analysis indicated a need for policies designed to

distribute the benefits and costs of technological change more equitably.

Martin (1972) was concerned with the income distribution impacts of the adoption of mechanical harvesting of cotton in the United States. An econometric model using time-series data was specified and estimated. In the partial equilibrium framework, Martin concluded that the United States as well as foreign consumers of United States produced cotton has experienced a welfare gain as a result of the adoption of the mechanical cotton harvester. Owners of land used to produce cotton in the United States have experienced a welfare loss while the impact on the United States society has been a welfare gain (Martin, 1972:133). A study of the labor market revealed that hired farm workers in the United States cotton-producing region have borne a major portion of the cost as they were displaced by the mechanical harvesters. Owners of land who were early adopters of the labor-saving technology tended to gain in the short run from increased returns to land. In the longer run, land values tended to decline slightly as the mechanical technology was adopted by most cotton producers (Martin, 1972:134).

CHAPTER III
METHODOLOGY

Introduction

A combine harvester is a machine which cuts a crop, removes the seed from the head or pod, separates the seed from the straw and cleans the seed (Phipps, 1967:541). Manual paddy harvesting involves cutting (reaping) the crop with a sickle, placing the crop on the stubbles, transporting it to the threshing area, threshing, sieving and winnowing.[1] Currently there are over 100 privately-owned units of the large combine harvester in the Muda Irrigation Scheme while 30 small ones are owned by the Muda Authority. In the following discussion, no distinction is made between the two categories.

It has been said that the emergence of the mechanical harvester in Muda was the result of acute labor shortage during the harvesting season (Jegatheesan, 1971:9, 11, 12, 23; 1974:34, 35; Tamin and Noah, 1974:10-12) coupled with the fact that harvesting is one of the most labor intensive operations in the paddy production cycle (Afifuddin et al., 1974:Table 8).

Ex-ante Considerations

The theory of induced innovation, as briefly reviewed in the previous chapter, postulates that changes in relative prices of inputs

[1] A detailed description of paddy harvesting operations, manually and mechanically, is available in Foster (1967).

influence the creation of a new set of production isoquants in the economy. This theory, while providing useful insight into the process of technical change, does not offer much explanation regarding producers' decisions to shift from the old unit isoquant to a new one. That is, the theory does not venture to explain producers' decision to adopt or use a new technology, such as the combine harvester. The approach used in the following discussion is based on fairly simplistic behavioral models in which the decision variable (dependent variable) is influenced by certain characteristics of the actor and his environment.

There are three dependent variables of interest in connection with this technical change: first, the decision to adopt or not to adopt (y_1); second, the extent to which the new technology is adopted (y_2); and finally, how early to adopt the new technique (y_3). The term "to adopt" refers to the implementation of the decision to contract for the use of combine harvester. The main concern of this section is to develop conceptual models which might be used to "explain" each of these dependent variables and to state the relevant hypotheses to be tested in Chapter IV.

Letting Y be an N-component vector of observations of a dependent variable and X be an N x K matrix of observations on the explanatory (independent) variables, the functional relationship between Y and X is

$$[3.1] \qquad Y = \phi(X, U)$$

where U is an N-component vector of random disturbances which makes equation [3.1] a stochastic relationship. The relationship expressed by [3.1] does not necessarily imply causality in the $X \rightarrow Y$ direction but merely association in the statistical sense between X and Y.

Implicit in [3.1] is the assumption that the columns of X are linearly independent, so that the inverse of X'X exists, which requires that the matrix X be of full column rank. We turn now to the specification of X based on knowledge gained from the literature review and from the Muda area itself.

Farm Size (x_1)

It is conventional wisdom, as the literature review has shown, to include farm size as an independent variable[2] to explain choice of a new technology. The combine harvester in Muda is no exception. Afifuddin states:

> Mechanization for rapid harvesting is very critical especially in the harvest season which coincides with a period of high rainfall. The entire operation has to be telescoped to two weeks per crop to cut, thresh and winnow. (1974:43)

This condition means that, ceteris paribus, larger farms with a lower ratio of labor to land are more likely to adopt the combine harvester than the smaller ones in order to avoid risk of bad weather. These farms are also more likely to fall within the group of early adopters.

---

[2]Theoretically, adoption of machinery may lead to larger farm size, in the long run, with the possible eviction of tenants by owners who want to work the land themselves. This should have taken place in the case of the tractor. The available data, however, do not support this theory. According to Jegatheesan (1976:24), analysis of various data pertaining to the period 1955-1974, showed that there has been no significant change in the mean farm size. Furthermore, eviction of tenants in Muda is rare, which is explained by the fact that the vast majority of tenants in Muda are, in fact, blood relations of landlords. Also, data collected in this study did not show any significant changes in farm size in the last three or even six years either for adopters or nonadopters.

If extent of adoption (y_2) is measured by the proportion of the farmer's paddy land harvested by machine, then we would expect, a priori, as farm size grows, the proportion of land harvested by the machine would increase but probably at a diminishing rate, and then it may decrease after a certain size is reached. This relationship is quite plausible bearing in mind the various problems of achieving 100 percent mechanization for large farms in the Muda area.

If "extent" of adoption is measured by the actual acreage harvested by the machine, then it is likely that "extent" tends to depend directly on the farm size. Designate the actual acreage mechanized as y_{20} and call this the "demand" for the contract service.

The above statements imply the following set of hypotheses:

$$\partial y_1/\partial x_1 > 0 \qquad \text{(Adopt)}$$

$$\left.\begin{array}{ll} \partial y_2/\partial x_1 > 0 \\ \partial^2 y_2/\partial x_1^2 < 0 \end{array}\right\} \qquad \text{(Proportion of land mechanized)}$$

$$\partial y_{20}/\partial x_1 > 0 \qquad \text{("Demand")}$$

$$\partial y_3/\partial x_1 > 0 \qquad \text{("Earliness")}$$

where x_1 is the farm size. Thus, in the "proportion of land mechanized" equation, farm size enters in a quadratic form.

Schooling (x_2)

The inclusion of schooling or elementary education among the set of variables to explain adoption of a new technique needs little elaboration. There are many compelling reasons for viewing education as

an explanatory variable. Gittinger states that

> . . . elementary education programs will develop in the child the habit of turning to the printed page for information about new technology, and for many years to come, at least, the printed work must remain the most common source for information about new technology, even in semi-literate societies. (1968:253)

Welch (1970:42) asserts that "increased education may enhance a worker's ability to acquire and decode information about costs and productive characteristics of other inputs." Additional schooling also increases the economic productivity of farm labor, and total farm income may well increase since farmers with more schooling will organize production more efficiently than farmers with a lower level of schooling (Gisser, 1965: 582).

Mechanization to many farmers is synonymous with modernization and progress (Pothecary, 1970a:420) and generally it is true that farmers with more schooling tend to be more "modern" in their outlook. This is so because education changes farmers' attitudes toward science and makes them more receptive toward results of research (see also, McPherson and Reitz, 1974). For example, a study by Wiransinghe (1977:67) in Sri Lanka showed that the number of years of schooling of the farm operator and average schooling (years) of the family members were highly statistically significant in determining the "rice farming knowledge" of the farmer, in a regression framework.

Tenure Status (x_3, x_4)

Traditionally, Muda paddy farmers have been divided into three distinct tenure categories; namely, the full owner-operators who do not rent in additional land, the full tenants who rent in all of their land

and the part-owner, part-tenant group (see, for example, Afifuddin et al., 1974 or Jegatheesan, 1976).

The influence of tenure on agricultural productivity has been a controversial topic. The belief that tenure can affect productivity in agriculture has led to various kinds of land reforms in many countries, such as Taiwan, Japan, Mexico and others. It is not the intention here to go into the various evidence that show tenure can affect productivity in agriculture in one way or another. The interested reader may refer to Raup (1967), Hayami and Ruttan (1971), Warriner (1964), Dorner and Kanel (1971), Long (1961), Schiekel (1969) and the bibliographies cited therein.

Jegatheesan writes:

> Available evidence on productivity and tenure relationships, while being unsatisfactory, does suggest that farmers in the tenant and owner-tenant categories do in fact achieve higher yields per unit area of land than owners [which] is quite consistent with the observation made by Hayami and Ruttan that tenants frequently achieve higher yields than owner-operators. (1976:37)

There is, however, very little empirical evidence to show whether tenants are more or less likely to use the service of contract machinery compared with other tenure groups. From the preliminary visits to Muda, it was learned that some farmers rejected the idea of the combine harvester because of the machine's tendency to "damage" the land. Thus, tenants were likely to be prevented by landlords from employing the combine harvester if the landlords really believed the damaging effect of the machine on the soil (see also, Mangahas, 1970:29).

On the other hand, if one believes that "tenants are more motivated to achieve higher output [and reduce costs] by having to meet rent payments" (Jegatheesan, 1976:39), then one would be inclined to expect

tenants to be more likely to adopt the combine harvester. These opposing possibilities tend to suggest that, a priori, it would be difficult to postulate a set of definite hypotheses about the influence of tenure status on the adoption, level or earliness of use of the combine harvester. The data will have to resolve this issue.

Fragmentation (x_5)

A farm may be considered fragmented if it is made up of several noncontiguous plots or "parcels." For a given farm size, the more parcels there are, the more fragmented it is. Hence, "fragmentation" is a function of farm size as well as the number of parcels. The empirical measurement of this variable will be discussed in the next section.

The combine harvester is a gigantic machine which must move across farm boundaries to perform its specific task. Some of the technical problems in the use of the combine harvester include difficulty of movement in small plots, difficulty in crossing bunds, bogging, transfer of rice from combines' bulk tanks to bags, and difficulty of entry into the field during the off-season when fields are full of water (MADA, 1970b: 7). Inukai observes the following with respect to tractorization in Thailand:

> The relation between fragmented holdings and the spread of tractor farming is often misunderstood. It is widely believed that the fragmentation of holdings hinders the advancement of tractor cultivation. This is certainly not true. It does not matter how fragmented and small the plots are. Provided all the farmers in an area agree to use tractors for ploughing, the tractor can plough the land back and forth as if the land were a single plot. Only when some of the farmers owning plots in the area oppose the use of tractors does fragmentation become an obstacle. (1970:480)

The same cannot be said for combining if different plots ripen at different times, however slight the difference is.

A farmer whose farm is greatly fragmented, ceteris paribus, is not likely to achieve full mechanization in his harvesting operation compared with another farmer whose farm is less fragmented. On the other hand, the more fragmented farm has a greater likelihood of adopting the new technology, if "adoption" merely means the decision to use the service regardless of the extent of use. This seemingly paradoxical proposition may be rationalized if it is realized that the farmer with the fragmented farm is more likely to have at least one parcel of his land lying adjacent to another farmer's land which is being harvested mechanically. Visits to Muda have shown that combining often takes place on several adjacent farms simultaneously, after which the harvest is divided among the farmers on a pro rata basis.

The foregoing would seem to suggest the following set of hypotheses:

$$\frac{\partial y_1}{\partial x_5} > 0 \qquad \text{(Adoption)}$$

$$\frac{\partial y_2}{\partial x_5} < 0 \qquad \text{(Extent of adoption)}$$

$$\frac{\partial y_{20}}{\partial x_5} > 0 \qquad \text{(Demand for mechanization)}$$

$$\frac{\partial y_3}{\partial x_5} > 0 \qquad \text{(Earliness of adoption)}$$

where x_5 is the degree of fragmentation.

Sex of Respondent (x_6)

Sex is a demographic characteristic of the farmer and is included as an explanatory variable to enable a testing of the null hypothesis that male and female farmers do not display any difference in their pattern of adoption of the new mechanical technology.

Perception of Economic Advantage (x_7)

The theory of induced innovation and its later modification postulated that changes in relative prices induce new technologies to be developed which will save the relatively more expensive factor. We hypothesize here that similar changes in relative prices induce farmers to adopt the new technology which was previously made available to them, provided that they have perceived the cost advantage of the new method. It is assumed that farmers operating with perfect knowledge will act rationally to reduce costs. Therefore, if they perceive a new technique to be cost-reducing, they will adopt it. Thus, if farmers choose the more expensive techniques, ". . . but are ignorant of doing so, [the act] is attributed to a lack of knowledge" (Welch, 1970:43).

Perception of Better Grain Recovery (x_8)

Preliminary investigation in the study area tends to suggest two diametrically opposed views on the grain recovery rate of the combine harvester vis-a-vis the traditional method of hand reaping and threshing. One group claimed that manual threshing resulted in greater grain loss (lower recovery rate) compared with the combine harvester, while the other group held the opposite view. Presumably, the first

group constituted the majority of the adopters, with the second group constituting a good percentage of the nonadopters. Here we meet with the question of technical efficiency in production and ". . . production is technically efficient if producers do not knowingly waste resources. If they waste resources but are ignorant of doing so, the loss is attributed to a lack of knowledge" (Welch, 1970:43). Thus, if farmers perceive the greater technical efficiency of the combine harvester, we hypothesize that they, as rational economic beings, will tend to choose the combine rather than manual method of harvesting. This is consistent with the ideas of the choice-of-technique school.

Neighborhood Effect (x_9)

This variable is intended to reflect two separate effects--namely, environmental and social. Availability of the machine to an area depends on the terrain of the area in question. It is reasonable to assume that a machine must be available in an area before a farmer can summon its service. Griliches states:

> It does not make sense to blame the Southern farmers for being slow in acceptance, unless one has taken into account the fact that no satisfactory hybrids were available to them before the middle nineteen-forties. (1957:507)

A similar remark could apply to any kind of new technology. While availability in the hybrid corn case was conditioned by economic factors, availability of the combine in Muda is to a large extent determined by accessibility, which is, in turn, a function of terrain or physical environment.

On the social side, the neighborhood variable is intended to reflect what is commonly known as the band-wagon effect, the demonstration effect or the desire to keep up with the neighbors.

Thus, a farmer who reports that a neighboring plot had been harvested by machine is more likely to summon the service of the machine himself, than a farmer who reports in the negative. Neighbors often serve as important "communication channels" (Rogers and Shoemaker, 1971:251) in the diffusion of new technology in agriculture.

Age (x_{10})

Age is a farmer characteristic often used as an explanatory variable in the adoption process. Rogers and Shoemaker (1971:185-186), however, postulate that earlier adopters are not different from later adopters in age and cite inconsistent evidence about the relationship of age and innovativeness.

Labor Availability (x_{11})

If the major reason for adoption of a machine was labor shortage within the farm household, then households with ample supply of labor would be less likely to use a machine, ceteris paribus. This implies the following set of hypotheses:

$$\frac{\partial y_m}{\partial x_{11}} < 0 \qquad (m = 1, 2, 20, 3)$$

Full-time Status (x_{12})

The full-time farmer may regard farming as his way of life and want to do the various operations using his own labor. He may regard the tediosity of manual operation as part and parcel of farming. On the other hand, the full-time farmer may regard farming as a business and source of income. He may, therefore, want to keep abreast with "modern" technology and be a better farmer. To this group, therefore, machinery "is in." Consequently, it would be presumptuous to state a definitive hypothesis concerning the effect of this categorical variable on the dependent variable.

Farmers' Association Membership (x_{13})

Although none of the 27 Farmers' Associations in the Muda area owns a combine harvester, the service of the smaller type of machine is made available to farmers through the FA's by MADA. It is hypothesized that members of the FA's, because of their closer contact with the authority, are more likely to adopt mechanized harvesting than nonmembers.

Summary of Hypotheses

Hypotheses of this study are summarized in Table 4.

In the following section the measurement of variables, the analytical models, and empirical estimation procedures are discussed.

Table 4. Hypotheses with respect to signs of the independent variables

Independent variables	Dependent variable			
	"Adopt"	"Extent"		"Earliness"
	(y_1)	(y_2)	(y_{20})	(y_3)
Farm size (x_1)[a]	+	+, -	+	+
Schooling (x_2)	+	+	+	+
Owner (x_3)	?	?	?	?
Tenant (x_4)	?	?	?	?
Fragmentation (x_5)	+	-	+	+
Sex (x_6)	?	?	?	?
Economic advantage (x_7)	+	+	+	+
Recovery rate (x_8)	+	+	+	+
Neighborhood (x_9)	+	+	+	+
Age (x_{10})	?	?	?	?
Labor availability (x_{11})	-	-	-	-
Full-time status (x_{12})	?	?	?	?
Farmers' association member (x_{13})	+	+	+	+

[a] A nonlinear relationship is postulated between farm size and y_2, the proportion of land harvested mechanically--hence, both (+) and (-) appear under y_2.

Measurement of Variables

Dependent Variables

Adoption (ADOPT) -- y_1. This is a dichotomous variable whose value equals 1 if any part of the farmer's paddy land was harvested by a machine and equals 0 otherwise.

Extent (PER) -- y_2. PER is measured by dividing the farm area harvested mechanically by the total paddy area operated. Thus, PER is the proportion of total paddy land of the farmer harvested mechanically in the second cropping season in 1977 (July-December) or (if that crop failed) the first season in 1978.

Extent (ARCOM) -- y_{20}. ARCOM Is the actual area of the farmer's paddy land that was harvested mechanically (combined) in the season referred to earlier.

Earliness (TIME) -- y_3. TIME was obtained by asking the farmer the number of times (i.e., seasons) he had harvested his paddy mechanically, including the season prior to the interview. Thus, "earliness" is a direct function of TIME.

Independent Variables

Farm size (FSIZE) -- x_1. This measurement was obtained by asking the farmer to state his farm size in the local unit relong.[3] This "raw" local unit was used in all the multivariate analyses although in the

[3] Relong = 0.711 acre = 0.288 hectare.

bivariate cases the farm size was first converted to the more "standard" unit acre.

Schooling (SCH) -- x_2. Schooling is simply the number of years a farmer reportedly had attended school regardless of the type of school--secular or religious. This implies the assumption that there is no difference in the quality of these two streams of schooling in influencing the allocative ability of farmers.

Tenure: Owner (OWN) -- x_3. This is a categorical variable which takes the value of 1 if the entire paddy land operated is owned and 0 otherwise. Three tenure types are distinguished in this study. To avoid linear dependence in the X matrix, only two "dummy" categories need to be specified. The excluded category is the part-owner, part-tenant group.

Tenure: Tenant (TEN) -- x_4. TEN takes the value of 1 if the entire paddy land operated is rented land and 0 otherwise.

Fragmentation (FMN) -- x_5. Fragmentation is a function of farm size (FSIZE) and number of parcels (PCL) operated. Intuitively the function should have the following properties:

$$\partial(FMN)/\partial(FSIZE) < 0$$
$$\partial(FMN)/\partial(PCL) > 0$$

As a practical matter, an index of fragmentation could be written as

$$FMN = PCL/FSIZE$$

which meets the stated properties.[4] However, to avoid the possible confounding effect of FSIZE on FMN, the number of parcels (PCL) was used as a proxy for the fragmentation index. Therefore, the coefficient of PCL measures the effect of PCL upon the dependent variable after controlling for the effects of all other explanatory variables, including the farm size, i.e., holding all other variables constant--ceteris paribus condition.

Sex (SEX) -- x_6. Female respondents were given the value of 1 and males the value of 0.

Perception of economic advantage (ECON) -- x_7. Farmers were asked whether they think that the mechanical harvester was cheaper to use than manual labor to harvest paddy. Four answers were allowed--yes, no (dearer), no difference and don't know. A "yes" answer was coded as 1 and the other responses were coded as 0 for the analysis.

Perception of better grain recovery (RCV) -- x_8. This measurement was obtained by asking farmers whether they thought that the machine recovered a higher percentage of the grain threshed than manual workers. Like the ECON variable, answers were given codes of 1 to 4 for "yes," "no" (worse), "no difference" and "don't know," respectively. As with x_7, codes 2, 3 and 4 were later recoded as 0 for the RCV variable.

---

[4] Bardhan (1973:1374) used a similar definition of fragmentation in a production function analysis using farm-level data from Indian agriculture.

Neighborhood effect (NHBR) -- x_9. Farmers were asked if any of their neighbors in the field[5] had used the service of the combine harvester. A "yes" answer was coded 1 and "no" was coded 0.

Age (AGE) -- x_{10}. Age was recorded in years at the last birthday. For the cross tabulations, AGE was recoded into discrete groups.

Labor availability (LABOR) -- x_{11}. This variable was measured by recording the number of adult equivalents available to do full-time harvesting work on the farm. Children 17 years old and below were given a weight of 1/2. Strictly speaking, LABOR measures the potential labor availability of the household.

Full-time status (FUL) -- x_{12}. A farmer was considered a full-time farmer (coded 1) if he derived more than 50 percent of his income from paddy production. Otherwise, he was coded 0 for this variable.

Farmers' association membership (FAS) -- x_{13}. All Farmers' Association members were coded 1 and nonmembers were coded 0.

Analytical Procedures

Logistic Regression

The standard approach in measuring the relative contributions of the variables contained in the X matrix toward y is multiple regression analysis with the variables used in their linear form. However, various difficulties will be encountered in using the classical least squares

[5]Farmers may be neighbors in the village but they may not be neighbors in the field as they may operate in different locations.

technique in quantifying the relative contributions of the various components of X toward a dichotomous dependent variable, y.

Recall that y_1 can take only two possible values, 1 if a farmer adopted a mechanical harvester and 0 if he did not. Therefore, the disturbance term u can only take on two possible values. If

$$y_{1_t} = 1, \qquad u_t = 1 - \beta' x_t$$

and if

$$y_{1_t} = 0, \qquad u_t = -\beta' x_t \qquad (t = 1, \ldots, N)$$

The assumption of homoskedasticity is, therefore, violated.[6]

Goldberger (1964:248) and Zellner and Lee (1965:387) have suggested generalized least squares to overcome the homoskedasticity problem but the GLS approach is only good asymptotically (Nerlove and Press, 1973:7). There is also no guarantee that $\hat{y}_t$ will be within the unit interval for all t, so that some of the "variances" may be negative.

Nerlove and Press (1973) discuss two improved approaches in analyzing binary data; namely, probit and the logit analysis. The choice of the technique in empirical work is quite arbitrary (Maddala and Nelson, 1974:3). A convenient one to use is the logistic function (Nerlove and Press, 1973:12).[7]

---

[6] Nerlove and Press (1973:5) note that y_t is a Bernoulli random variable with $E(y_t|x_t) = \beta' x_t$ and var $(y_t|x_t)$ = var (u_t) = $\beta' x_t(1 - \beta' x_t)$. Since var (u_t) depends upon t, the disturbance terms are heteroskedastic, and the use of OLS will give inefficient estimators and imprecise predictions.

[7] See, for example, Theil (1967:73) and Nerlove and Press (1973:11). Other examples of studies which used the logit analysis may be found in Boskin (1974), Demir (1976), Schmidt and Strauss (1975a, 1975b), Miklius and Casavant (undated).

Let p_t be the probability that the t^{th} farmer will use the combine harvester. Hence,

$$p_t = Pr(y_t = 1) = Pr(u_t < \beta' x_t)$$
$$= F(\beta' x_t)$$

where F is the cumulative distribution function (cdf) of the random variable u_t. Obviously, $1 - p_t = Pr(y_t = 0) = 1 - F(\beta' x_t)$. With this specification, p_t will lie between 0 and 1, being a property of the cdf (Meyer, 1965:62), since $F(-\infty) = 0$ and $F(\infty) = 1$.

The logistic function is given in equation [3.2].

$$[3.2] \qquad p_t = [1 + \exp\{-\beta' x_t\}]^{-1}$$

Solving for the argument, we get

$$[3.3] \qquad \exp\{-\beta' x_t\} = (1 - p_t)/p_t$$

Taking logs of both sides of [3.3] gives

$$[3.4] \qquad -\beta' x_t = \ell n[(1 - p_t)/p_t]$$

Hence,

$$[3.5] \qquad \ell n[p_t/(1 - p_t)] = \beta' x_t$$

The left-hand side of [3.5] is known as the log-odds or logit of machine adoption. The computational procedures for obtaining the estimates of the β's are given in Nerlove and Press (1973:88-98) together with a computer routine which was used in this study. The procedure

involves the setting up of a likelihood function in the parameters, β, and the maximization of this likelihood function, given observations on a dichotomous dependent variable and a set of independent variables (Nerlove and Press, 1973:88). Maximum likelihood estimators have the desirable property of asymptotic efficiency (Theil, 1971:392).

The derivation of the likelihood function of the logit is given in Appendix A.

Tobit Analysis

The Tobit model was used to explain the extent and earliness of mechanization. The choice of this model was based on the fact that over 70 percent of the respondents did not use the machine to harvest their paddy crop. Hence, the dependent variables of interest are truncated. A detailed discussion of the Tobit model is given in Appendix A.

Sampling Procedures

As stated in Chapter I, the bulk of the data for this study came from a series of surveys of farmers, farm workers, combine harvester owners and machine brokers. The sampling procedure adopted for each of these groups of people will now be described, while a summary of schedules used is given in Appendix B.

Farmer Sample

The selection of the 858 farmers was made according to the following (stratified, multi-stage random sampling) procedures. First and foremost, it was decided to confine the study to the three irrigation districts in Kedah because preliminary inquiries revealed that farmers

in District I (Perlis) did not use the machine during the harvesting season of 1977 (beginning July).

The sampling was done in the following manner. The 22 localities (FDA's) in the three districts were stratified into "high density," "medium density" and "low density" areas according to the following criterion. The Muda Agricultural Development Authority (MADA, 1978) in early 1977 conducted a sample survey which, inter alia, determined the percentage of farmers using mechanical harvesters in each locality. Based on this survey, the following frequency table was obtained (Table 5).

One locality was then randomly selected from each stratum, giving the following result:

Stratum (1): Locality 4D (22.2 percent) (Permatang Buluh) -- FDA3

Stratum (2): Locality 2A (7.2 percent) (Kodiang) -- FDA1

Stratum (3): Locality 3D (0 percent) (Titi Haji Idris) -- FDA2

An attempt was then made to list all farm households in each of the three localities. Figure 5 shows the geographic location of the sampled localities.

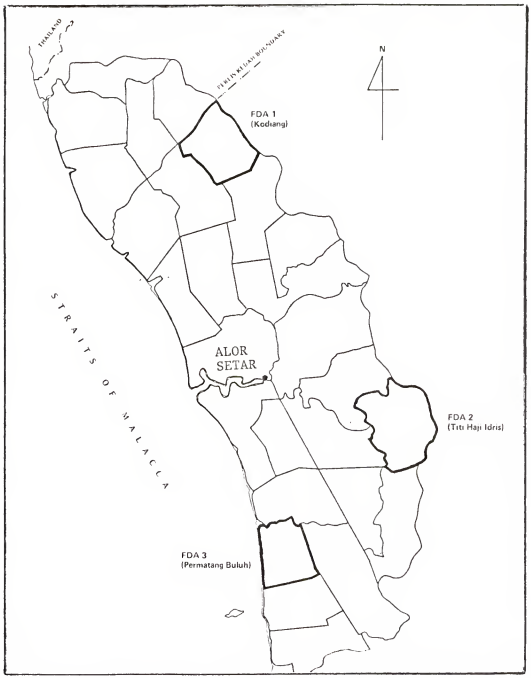
A simple random sample of farmers was then selected from each of the localities giving the following results (Table 6). The 858 farmers were interviewed in Phase I using Schedule A (Adoption Schedule).

In a second-round visit to the study area, 293 of the 858 farmers were interviewed for in-depth information on the use of the combine harvester. Prior to sampling, the 858 farmers were first stratified

Table 5. Distribution of strata

Stratum	Density of users	Number of localities
High	Over 15 percent	7
Medium	5-15 percent	7
Low	Under 5 percent	8
Total		22

SOURCE: Derived from MADA (1978:14).



SOURCE: MADA Headquarters

Figure 5. Map of Muda showing FDA locations and boundaries

Table 6. Distribution of sample by locality

Locality	Listed	Sample	
		Number	Percent of listed
Kodiang (2A)	956	300	31.38
Titi Haji Idris (3D)	1,048	304	29.01
Permatang Buluh (4D)	645	254	39.38
Total	2,624	858	32.39

into "adopters" and "nonadopters." A simple random sample of adopters and nonadopters was then selected from each locality and the distribution is given in Table 7.

Labor Sample

As in the case of the farmers, no sampling frame existed for the labor population. Therefore, a "frame" had to be created. Farmers interviewed during Phase II were requested to give names and addresses of farm workers whom they hired to do harvesting (reaping or threshing or both) during the previous season. A good majority of the farmers was able to provide the required information on the workers they hired although some could only provide first names. This condition, however, did not pose much of a problem since Malaysians are better known by their first names. A total of 563 farm workers was obtained from this exercise and a sample was then selected randomly from each locality giving the distribution by locality as shown in Table 8.

Combine Harvester Owner Sample

A listing of the combine harvester owners was attempted during Phase II to augment the list which was made available to the researcher by an undergraduate student researcher (Rayarappan, 1979). A total of 38 machine owners was ultimately listed for the interview during Phase II of the data collection exercise. The machine owners, however, were not restricted to the three FDA's, in which case the sample would have been too small for meaningful results. They were listed from all areas throughout the Muda irrigation scheme except Perlis, where there was no combine harvester.

Table 7. Distribution of farmers in the Phase II survey by locality

Locality	Number of adopters	Number of nonadopters	Total	Percent of Phase I
Kodiang	39	54	93	31.00
Titi Haji Idris	58	43	101	33.22
Permatang Buluh	39	60	99	38.98
Total	136	157	293	34.15
Prior Probability	0.46	0.54		

Table 8. Distribution of labor sample by locality

Locality	Number listed	Number in sample	Percent in sample
Kodiang	189	93	49.21
Titi Haji Idris	155	83	53.55
Permatang Buluh	219	139	63.47
Total	563	315	55.95

Combine Harvester Brokers

Combine harvester brokers are commission agents who make contact with farmers desiring to harvest their paddy crop mechanically through the contractual system. For this service they are paid a commission by the machine owners. As in the case of the farmers, workers and combine harvester owners, a "sampling frame" had to be devised. Names and addresses of brokers were collected during Phase II and, after processing and cleaning (e.g., removing duplications, etc.), a total of 59 brokers was obtained. All of them were interviewed during Phase III of the data collection exercise.

Characteristics of the Sampled Localities

It was fortuitous that each of the three irrigation districts in Kedah was represented in this study. These irrigation districts, however, do not coincide with the long-established administrative districts. The purpose now is to give a brief description of the three localities sampled in this study.

Kodiang locality is located to the north of Alor Setar, in the district of Kubang Pasu. The town is accessible from Alor Setar via two major roads. The traveling distance via either road from Alor Setar to Kodiang is about 25 miles (42 kilometers). The size of the locality is 10,463 acres with 8,857 acres occupied by paddy. The rest of the area is made up of mixed crops around farmers' houses, roads, canals, grassland, secondary jungle, etc. Kodiang locality has a population of about 10,000 people.

Titi Haji Idris Farmers' Association is situated 10 miles to the southeast of Alor Setar and is accessible by an all-weather road. This locality, in the district of Kota Setar, has a population of about 8,000 persons and a total area of 12,265 acres; 10,431 acres are in paddy. Rubber is an important second crop in this locality.

Permatang Buluh is about 17 miles by road south of Alor Setar. The locality is in a coastal zone and is protected from tidal ingress by a high bund and canal along the coastline. It has a population of about 5,000 and a total area of 10,100 acres, with 8,755 acres devoted to paddy cultivation.

Table 9 gives a summary of the characteristics of the three localities sampled in this study. The villages and mukims (subdistricts) covered by the survey are given in Appendix C.

Several interesting facts emerge from Table 9. For instance, over 80 percent of the area in each of the three localities were planted with paddy, which suggests a strong degree of monoculture in Muda as a whole. Actual figures are as follows: Kodiang, 84.66 percent; Titi Haji Idris, 85.05 percent and Pematang Buluh, 86.68 percent.

Another interesting feature is that Titi Haji Idris has the highest percentage area (16.53 percent) devoted to mixed crops. These include mainly rubber and to a lesser extent fruit trees. The equivalent figure for Kodiang is 8.44 percent and for Permatang Buluh is 6.63 percent. Hence, in Titi Haji Idris paddy may not be the only source of farm income.

A third interesting facet of the physical characteristics of the sampled localities is Titi Haji Idris' high percentage (4.4 percent) of land occupied by swamps and streams compared with only 0.41 percent in

Table 9. Characteristics of the sampled localities

Item	Kodiang	Titi Haji Idris	Permatang Buluh
Population	10,000	8,000	5,000
Total area (acres)	10,463	12,265	10,109
Paddy area (acres)	8,857	10,431	8,755
Mixed crops (acres)	883	2,027	670
Built-up area (acres)	97	25	111
Roads, canals (acres)	796	740	634
Grassland, jungle (acres)	54	631	123
Swamps, streams (acres)	43	540	112
Other (acres)	33	441	58

SOURCE: Respective Farmers' Association bulletin board.

Kodiang and 0.57 percent in Permatang Buluh. This difference may have a bearing on the rate of diffusion of the mechanical harvester which has to physically move from place to place. It has been claimed that, aside from the high bunds, the combine harvester is not popular in Perlis (District I) because of the difficulty of moving the machine across the numerous streams and swamps.[8]

[8]This information was given by a combine harvester owner who lived in Perlis but contracted out his machine in Kedah during an interview with the author on July 29, 1978.

CHAPTER IV
ANALYSIS OF RESULTS

This chapter presents the results of the logit and Tobit analyses of data collected from the 858 farmers (Phase I). A general description of the characteristics of the sample is presented in Appendix D. The institutional arrangements that have emerged to cater to the demand for the new technology, characteristics of the various parties involved in this innovation and a general assessment of the gains and losses as a result of this technical change are presented in Appendix E.

Choice of Technology

The logistic estimates as described in Chapter III serve as the analytical tool in the investigation of the choice of harvesting technology made by farmers in the Muda Irrigation Scheme. The criteria used to evaluate the model and interpret the results include the estimated coefficients and their signs and the estimated standard errors of the estimated coefficients.

Maximum Likelihood Logistic Results

Results of the logistic analysis of choice of harvesting technology by Muda farmers are presented in Table 10. The coefficients were estimated by maximum likelihood procedures. The estimated standard errors are smaller than their respective estimated coefficients for the variables farm size (FSIZE), tenant (TEN), perception of economic

Table 10. Logistic relations for decisions to hire mechanical harvesting of paddy,[a] Muda Scheme, 1977-78

Independent variable[b]	Coefficient	Asymptotic S.E.	Asymptotic "t"
CONST	-5.608	0.813	6.896
FSIZE	0.156	0.035	4.488
OWN	0.120	0.271	0.445
TEN	0.286	0.278	1.025
PCL	0.104	0.136	0.770
SEX	-0.108	0.447	0.242
ECON	0.450	0.204	2.203
RCV	0.328	0.248	1.322
NHBR	3.074	0.313	9.832
AGE	-0.010	0.010	0.993
LABOR	-0.034	0.120	0.287
FUL	0.847	0.433	1.956
SCH	0.016	0.036	0.460
FAS	0.571	0.206	2.776
FDA3	0.706	0.271	2.610
FDA1	-0.050	0.264	0.192

Log of likelihood function = -331.09

[a] The function estimated is of the form

$$p(y = 1|X) = [1 + \exp\{-\beta'X\}]^{-1}$$

[b] The dependent variable is ADOPT = $\begin{cases} 1 \text{ if machine was used} \\ 0 \text{ otherwise} \end{cases}$

advantage (ECON), perception of technical advantage (RCV), whether a neighbor had used the machine (NHBR), full-time status (FUL), Farmers' Association membership (FAS) and residence in FDA3. These results suggest that these variables are important in influencing the choice of the new technology. The signs of the estimated coefficients were generally as hypothesized in Chapter III. The coefficients for variables owner (OWN), number of parcels, sex, age, labor availability, schooling and FDA1 dummy had large standard errors, suggesting that these variables contributed very little to the decision to use the combine.

The results indicate that, other things equal, the farmer operating a larger farm had a greater probability of using the machine to harvest his paddy than another farmer with a smaller acreage of land. Although this finding is to be expected, a brief interpretation is in order. Farmers in Muda are faced with a tight seasonal schedule since the inception of double-cropping. The harvesting season has been shortened from three or four months under single cropping to six weeks with double-cropping. Farm size, understandably, plays a crucial role in influencing the use of a combine harvester by these farmers who must grow two crops according to schedules set by the Authority. It is expected that farmers with larger farms, who must depend more on hired labor, must feel greater pressure to overcome labor shortages during the harvesting season.

Although this result is in agreement with findings of researchers working on the diffusion of biological technology (e.g., Gerhart, 1975; Cutie, 1975; Helleiner, 1975), the rationale for combining by Muda farmers may differ from that of farmers adopting the HYV's in

other countries. It appears that Muda farmers, especially those with large plots, attach a great deal of importance to timeliness. Staub and Blase (1974:593) found this to be true in the case of Indian farmers. Table A-14 of the present study gives supportive evidence of the importance of earliness and speed to farmers in the Muda area where 84 percent of the machine users interviewed said they chose the machine because it was faster.

The results show that tenants have a higher tendency to use mechanized harvesting compared with the mixed-tenure farmer--the group whose tenure dummy variable was excluded. The tenant's financial standing can be eroded by high land rentals. According to Afifuddin (1973:2), land rentals in the Muda area constitute 38 percent of the costs of paddy production. This cost is high by any standard. As a result of high rentals, tenants get only 47 percent of what the owner-operator gets from every acre of paddy land cultivated (Afifuddin, 1973:2).

The result seems to suggest that tenants were quite free from landlord intervention in the use of the machine for harvesting. It has been reported in the Philippines that, for certain innovations, tenants were required to obtain the permission of the landlords before embarking upon such innovations (Mangahas, 1970:29).

The available evidence indicates that fragmentation of land holdings in the Muda area has not been a hindrance to the use of the combine harvester. Farmers with a large number of parcels (PCL) were as likely to adopt mechanized harvesting as were farmers with few parcels. This finding is consistent with that of Inukai (1970:480) with regard to tillage in Thailand. In the case of mechanized harvesting by Muda

farmers, as long as the machines do not have to cross high bunds and streams, and as long as farmers cooperate with each other, fragmentation as measured by PCL is not a problem.

Sex did not contribute toward an explanation of the probability of machine use; i.e., other things equal, female farmers were as likely to choose the combine as were their male counterparts.

The results also indicate the rationality of Muda farmers in the sense that, once an innovation is perceived to be cost reducing, even though it may not be output augmenting, the innovation would be readily acceptable. There were only a very few farmers in Muda who would "knowingly waste resources," to quote Welch (1970). The scarcity of labor in the Muda area has driven up wage rates for manual harvesters in recent years. The machine is decidedly cost reducing on farms where labor must be hired.[1] The cost of hand labor may be less where the farmer's own family labor is employed; the wage rates may not accurately measure the opportunity cost of family labor. More important than the direct cost, perhaps, is the reduced time when mechanical harvesters are used. A ripened crop may be saved from climatic disaster.

Recovery rate (RCV) is a technical question which was clearly explained to the farmers during the interview. A measure of recovery rate is an indication of grain loss during the harvesting process. The evidence contained in Table 10 shows that farmers were also "technically" rational since those who perceived the greater technical efficiency of the combine harvester, with respect to the recovery rate, may have been more likely to choose the machine, other things equal.

---

[1] See Appendix E for an economic comparison between manual harvesting and mechanical harvesting.

Whether or not a neighbor had used the mechanical combine (NHBR) was intended to indicate machine availability as well as a possible demonstration effect, although admittedly the two effects cannot be separated by the use of one variable. The results could be interpreted to mean that neighboring conditions are important determinants of the adoption of mechanized harvesting in the Muda Scheme. Since a machine has to be available before a farmer can request its service, and since a farmer reporting that a neighbor had used the machine had a greater probability of adopting it, mechanized harvesting is likely to be widely diffused in a relatively short time once problems of bringing the machines into new areas are overcome. Once available to an area, farmers in that area will readily mechanize. There were only a few farmers who knew of the machine's availability and did not use it. The results can also be interpreted to mean that machine harvesting required close cooperation with neighbors and, for the service to be economical, the area harvested had to be large and contiguous but did not necessarily have to belong to one farmer. Furthermore, uniform ripening within and among fields is a prerequisite.

Age did not appear to be an important determinant in the adoption of mechanized harvesting in the Muda Scheme. This result is consistent with those reported by many other researchers (e.g., Mangahas, 1970; Demir, 1976; Helleiner, 1975) working on choice of HYV's. Afifuddin (1973:10), however, found age to be negatively correlated with the farmer's degree of commercialism or "commercial farming attitude" in his own terminology. Unfortunately, what was measured in Afifuddin's study was attitude and not observable actions; hence, the correlation obtained might not necessarily indicate that younger farmers were more

likely to adopt a new technology--it may only indicate an intention, which may never materialize.

A priori it is reasonable to expect that a farmer facing a labor shortage in his household would be more likely to mechanize his harvesting operations compared with those with ample potential family labor. However, the coefficient of LABOR in the logistic equation (Table 10) had a standard error larger than the coefficient. Labor availability, as measured by LABOR, turned out to help very little in explaining the decision to use the mechanical combine. This result suggests that the so-called labor shortage in Muda might really be the unwillingness on the part of the available family labor (particularly among the younger age groups) to perform the arduous harvesting task--perhaps with an attitude that, with better education, they were "meant for better things." Thus, having the potential labor was no guarantee that this labor would be employed to do manual cutting and threshing of paddy. Eventually, this idle labor would probably migrate to urban employment as unskilled, semi-skilled or clerical workers.[2]

From the results, it is clear that the full-time farmer in Muda was more likely to mechanize harvesting operations compared to the part-time farmer. This is in agreement with one of the two possibilities postulated in Chapter III, and it may suggest that the part-time farmer was still hiring manual labor to harvest his crop in the case where his own labor was required elsewhere, such as in small rural business or in

---

[2]MADA (1972:8) states:

> Rural-urban migration in the Scheme has not been the result of mechanization of the labor-intensive operations of transplanting and harvesting. Mechanization, therefore, has not been the cause of an outmigration of displaced rural labor.

Outmigration of labor may have been one of the causes of mechanization.

government service. The result also suggests that the part-time farmer might have made a long-term commitment with relatives or trusted friends regarding the harvesting operation, which in most cases would involve manual labor and is common among government servants. Helleiner (1975) cited several studies on the African continent which showed that degree of full-time commitment to farming was significant in explaining the adoption of a new technology. The part-time farmer who comes "on and off" the field to do occasional weeding or to check water levels or to bring food to workers might not be too concerned about new, improved techniques as long as he does not have to buy rice from the sundry shop. It is, however, recognized that some of these part-timers are "big timers" in that they belong to the class of larger farms.

Although the coefficient of the schooling variable (SCH) has the hypothesized positive sign, it is very much smaller than its asymptotic standard error. It, therefore, appears that years of school attendance may not contribute to the choice of the new harvesting technology in Muda. While the result is contradictory to the "human capital" hypothesis and to the results obtained by several other researchers working on technology diffusion (e.g., Gerhart, 1975; Demir, 1976; Colmenares, 1975; Bhati, 1973), there may be a reasonable explanation for this difference. The use of the combine contract service requires no previous skill, experience or special training on the part of the farmer. Every step in the harvesting operation is done for him; he needs only to bag the harvest in gunny sacks or to tell the machine driver spots in the field in which there is danger of bogging. Even the latter function is being assumed by the machine brokers. In short, the decision to choose the machine appears to be independent of the level

of schooling the farmer had. Mangahas states:

> This evidence should not be interpreted as opposing the hypothesis that the human factor in general is an important determinant of technology diffusion. It merely points out that the variable which best serves as an index of the human factor is not necessarily schooling as far as a particular innovation and a particular group of people are concerned. (1970:53)

The coefficient of FAS is positive, as hypothesized, and had a small estimated standard error in the logistic equation. The positive sign indicates that, other things equal, members of Farmers' Associations (FA's) have a higher probability of adopting mechanized harvesting compared with nonmembers. The result is not surprising in view of the dominating role of these associations in agricultural mechanization in Muda, particularly with regard to land preparation and, lately, to harvesting. Helleiner (1975:49) cited several diffusion studies in Africa in which participation in local organizations was statistically significant. Demir (1976), however, found the variable unimportant in all three logit equations he estimated with the use of data from Turkey. The other research reviewed did not explicitly incorporate membership in a farmer's organization in their analyses as was done in the present study. Although the FA's supply only a small proportion of the total mechanization of farmers, the major share is provided by the contract business, the FA is more than a supply depot; it is a meeting place for farmers, some of whom are machine brokers. The organization does appear to serve as an important communication channel for the diffusion of the new mechanical technology in the Muda Irrigation Scheme.[3]

---

[3]"The FA's are a high scope organization since they are multi-purpose and serve the interests of many social groups, [even] members of rival political parties and of different age groups" (Afifuddin, 1973:17).

Although not explicitly stated in Chapter III, the effects of the different localities (FDA's) on the probability of machine adoption were taken into account in running the logistic regression. Two locality dummy variables (with 0, 1 values) were included in the probability equation. The "excluded" locality was FDA2, viz., Titi Hj. Idris. The regression coefficients have to be intrepreted as differences between the effect of the relevant locality and the excluded locality. The coefficient of FDA3 was positive with a very small estimated standard error, which suggests that farmers in FDA3 were more likely to adopt the machine than those in FDA2, given the same other attributes. This result is not unexpected since the sampling procedure had already selected FDA3 from among the "high density" localities as far as mechanized harvesting was concerned. Knowing from which stratum (see Chapter III) a farmer came, and a vector of the other independent variables, one may predict the probability that the farmer will choose mechanized harvesting. The preponderance of machine users in FDA3, compared to FDA2, could perhaps be explained by the nearness of the locality to the town of Tokai, where over 90 percent of the private contractors resided (see Rayarappan, 1979); harvesting dates were more uniform and there was an absence of large streams and deep swamps which might otherwise make access rather difficult.

Predicting and Sensitivity Analysis

Some applications of the logistic estimates and the question of measuring the responsiveness of the probability of machine use with respect to small changes in certain independent variables are now considered. First, consider the probability that the t^{th} farmer with

a given set of characteristics will adopt mechanical harvesting. This is the familiar concept of conditional predictions. As an example of how the estimated coefficients may be used, consider a hypothetical farmer who is full-time, male and of average age, who has an average farm size, parcel number, potential household labor and schooling and who perceived the economic as well as technical advantages of the machine and whose neighbor had used the machine. What is the probability that he will choose the machine when his tenure status, FA membership status and residence are known? By inserting the values of these explanatory variables into the logistic equation, one may calculate that conditional probability. Table 11 gives the conditional probability of machine adoption by hypothetical farmers for different FDA's, tenure categories and FA membership status. For example, a tenant farmer in FDA3, who is a member of an FA in this locality, had a probability of using the machine which exceeds that of owners by 0.7699 - 0.7392 = 0.0307.

One may now consider the question of responsiveness of the probability of adoption to small changes in certain explanatory variables. Since $p = [1 + \exp\{-\Sigma_i \beta_i x_i\}]^{-1}$, it may be shown that $\partial p/\partial x_i = \beta_i p(1 - p)$. Hence, the elasticity of probability with respect to the i^{th} variable η_{pi} is given by

$$\eta_{pi} = \beta_i(1 - p) x_i$$

The elasticity depends on the value taken by all explanatory variables.

The elasticity may be evaluated at the means of these explanatory variables as was done for prediction. This was done for farm size

Table 11. Predicted probability of machine adoption by full-time "average" male farmers by locality, tenure group and membership in Farmers' Association, Muda Scheme, 1977-78

Locality[a]	Owners		Tenants		Mixed tenure	
	FA members	Nonmembers	FA members	Nonmembers	FA members	Nonmembers
	Probability					
FDA1	0.5709	0.4292	0.6110	0.4702	0.5413	0.4000
FDA2	0.5831	0.4414	0.6229	0.4827	0.5537	0.4121
FDA3	0.7392	0.6155	0.7699	0.6540	0.7154	0.5868

[a] The mean values for the entire sample of 858 farmers were used for the following independent variables:

FSIZE = 5.22
PCL = 1.73
AGE = 43.3
LABOR = 2.09
SCH = 3.97

ECON, RCV and NHBR were set to 1 and the other dummy variables were set to 1 if they were represented by the cell being estimated, or 0 otherwise.

(FSIZE) for the 18 categories of farmers contained in Table 11. These elasticities are given in Table 12. The elasticity figure of 0.3494 for owners who were FA members in FDA1 means that a 1 percent change in the farm size is associated with a change in the probability of machine use of 0.35 percent.

Tobit Analysis of Extent of Mechanization

The two limited dependent variables are the proportion (expressed as a percentage) of the farmer's land that was mechanized (PER) and the actual area that was mechanized (ARCOM).[4]

Table 13 gives the results for the percentage of land mechanized. An overall test of significance was performed by using the likelihood ratio test. The unrestricted model had 16 independent variables including the square of farm size. The restricted model had only the constant term. The logarithm of the likelihood ratio obtained was 172.83 which gave a test statistic of 345.66, distributed as a χ^2 statistic with 16 degrees of freedom. The critical value for $\chi^2_{.005}(16)$ is 34.267. Hence, the null hypothesis that the set of independent variables did not influence the percentage of land mechanized was rejected at the 0.005 level of probability.

Nine of the 16 independent variables have coefficients with small standard errors; namely, farm size (FSIZE), size of farm squared, perception of economic advantage (ECON), perception of technical advantage (RCV), neighbor's action (NHBR), age (AGE), full-time status (FUL), Farmers' Association membership (FAS) and the locality dummy (FDA3).

[4] PER ranged from 7 percent to 100 percent with a mean of 64.29 for users. The overall mean was 17.61 percent. ARCOM ranged from 0.5 to 22 relongs.

Table 12. Estimated elasticity of probability of adoption with respect to farm size evaluated at the mean of farm size, Muda Scheme, 1977-78

Locality[a]	Owners		Tenants		Mixed tenure	
	FA members	Nonmembers	FA members	Nonmembers	FA members	Nonmembers
	Elasticity					
FDA1	0.3494	0.4648	0.3168	0.4314	0.3735	0.4886
FDA2	0.3395	0.4549	0.3071	0.4212	0.3634	0.4787
FDA3	0.2124	0.3131	0.1874	0.2818	0.2318	0.3364

[a] The formula used is $\eta_{p_{jk}} = \beta_1(1 - p_{jk})\, x_1 = .156(1 - p_{jk})\, 5.22$ and the value of p_{jk} is obtained from Table 11.

Table 13. Results of Tobit analysis of percentage of paddy land harvested mechanically, Muda Scheme, 1977-78 (dependent variable = PER)[a]

Independent variable	Coefficient	Asymptotic "t"	Elasticity[b]	
			Index	$E(y_2)$
CONST	-188.710	7.234		
FSIZE	6.688	3.354	1.419	0.666
$FSIZE^2$	-0.182	2.525		
OWN	6.996	0.765		
TEN	8.663	0.937		
PCL	2.023	0.448	0.199	0.093
SEX	-2.321	0.150		
ECON	20.765	2.950		
RCV	9.565	1.153		
NHBR	106.628	11.717		
AGE	-0.407	1.253	-1.000	-0.470
LABOR	0.313	0.077	0.037	0.017
FUL	29.335	2.008		
SCH	0.797	0.667	0.180	0.084
FAS	16.436	2.353		
FDA3	27.657	3.032		
FDA1	-5.874	0.657		

Log of likelihood function:

Unrestricted model = -1514.04

Restricted model (with CONST only) = -1686.87

$-2 \ell n \lambda = 345.66^{*} \sim \chi^2$, 16 d.f.

[a] NOTE: Number of limit observations = 623
Number of nonlimit observations = 235

[b] The elasticities with respect to dummy variables have no meaningful interpretation and were left out.

* Significant at 0.005 level.

Furthermore, all nine coefficients have the expected signs. The effect of farm size on the proportion of land harvested is curvilinear. Table 13 also gives the elasticity measures with respect to the index and with respect to the expected value of y_2, the dependent variable.

Apart from the tenant dummy variable (TEN) and the introduction of farm size squared, all variables, whose coefficients had small standard errors in the logistic model, displayed a similar set of characteristics in the Tobit model. With respect to farm size, the proportion mechanized increases at a decreasing rate. The underlying effect of farm size, after taking into account the quadratic term, is given by

$$\frac{\partial PER}{\partial FSIZE} = \beta_1 - 2\beta_2 \, FSIZE$$
$$= 6.688 - 0.364 \, FSIZE.$$

When evaluated at the means, this slope is 4.78 with a standard error of 1.281. One reason for introducing farm size squared as a variable is the fact that there is an upper limit of 100 percent in PER.

We now turn to the actual area combined. An overall test of significance by the likelihood ratio test gave a test statistic of 429.46 (Table 14), which is distributed as a χ^2 statistic with 15 degrees of freedom. The critical value for $\chi^2_{.005}(15)$ is 32.801; hence, the null hypothesis that the coefficient vector equalled the null vector was rejected at the 0.005 level of probability, i.e., the independent variables postulated to influence the area mechanized did collectively exert influence to a significant degree.

The Tobit estimates for farm size (FSIZE), perception of economic advantage (ECON), neighbor's decision (NHBR), full-time status (FUL), Farmer's Association membership (FAS) and the locality dummy variable

Table 14. Results of Tobit analysis of actual area of paddy land harvested mechanically, Muda Scheme, 1977-78 (dependent variable = ARCOM)[a]

Independent variable	Coefficient	Asymptotic "t"	Elasticity	
			Index	$E(y_{20})$
CONST	-12.937	7.948		
FSIZE	0.499	8.663	2.334	1.195
OWN	0.215	0.396		
TEN	0.432	0.771		
PCL	0.168	0.621	0.261	0.134
SEX	-0.542	0.553		
ECON	1.216	2.824		
RCV	0.439	0.865		
NHBR	6.637	11.591		
AGE	-0.016	0.827	-0.633	-0.324
LABOR	0.028	0.115	0.053	0.027
FUL	1.523	1.669		
SCH	0.055	0.754	0.194	0.099
FAS	1.132	2.671		
FDA3	1.746	3.125		
FDA1	-0.166	0.303		

Log of likelihood function:

Unrestricted model = -842.88

Restricted model (with CONST only) = -1057.61

$-2 \ell n \lambda = 429.46^{*} \sim \chi^2$, 15 d.f.

[a] NOTE: Number of limit observations = 623
Number of nonlimit observations = 235

*Significant at 0.005 level.

(FDA3) all have small standard errors and the hypothesized signs. Thus, for instance, the area combined varies directly with farm size, ceteris paribus. Again, farmers who perceived the economic advantage (ECON) tended to harvest a larger area by machine than those who did not perceive the cost advantage of the new technology, other things equal. The remaining variables did not appear to be important in influencing the area mechanized. Farm size squared as a variable was left out of this model because there is no upper limit to the dependent variable.

The ARCOM equation may be considered as a type of "demand for machine" equation as it could be used to predict the actual acreage to be harvested by machine. The equation lacks a price variable, which is not uncommon for cross-sectional studies.[5] This ACROM equation would be analogous to an Engel function in demand studies.

Earliness of Use

A Problem with the Dependent Variable

The dependent variable (y_3), "earliness of use" of the mechanical harvester, is measured by the number of previous seasons the farmer had used the machine. Since y_3 depends partly on past events, it is not truly endogenous in the strictest sense.[6] Hence, to "explain" y_3 by

[5] Apart from the lack of sufficient variability in the price charged by the machine contractors, many farmers did not know the price charged for contract harvesting by the combine operator. These two considerations precluded the use of price in this equation. The ECON variable was meant to be a proxy for price.

[6] Note that y_3 is the "sum" of the occurrence of "ADOPT" in the past. This sum is designated as "TIME" in the analysis. Therefore, part of "TIME" is not contemporaneous with some explanatory variables, in the sense that some of these variables may have occurred after adoption.

regressing it against variables such as ECON, RCV and NHBR (which were observed in 1978) may not be strictly correct and requires the bold assumption that these explanatory variables have not changed since the time of first use. Thus, for example, it is assumed that a farmer who said it was cheaper to harvest mechanically in 1978 actually held this view from the time of first use. Whether this assumption holds true is not known. There is, however, evidence to show that the tenure status and farm size operated by farmers in general have not changed substantially in the three years just prior to the survey. Hence, it appears admissible to use farm size, tenure, etc., as independent variables to explain earliness of use.

Overall Test of Significance

An overall test of significance was conducted on the earliness of use model, as was done with the extent of use models. The test statistic obtained was 377.64, distributed as a χ^2 with 15 degrees of freedom (Table 15). The critical value for $\chi^2_{.005}(15)$ is 32.801. The null hypothesis that the coefficient vector in the Tobit equation of earliness of use equalled the zero vector was rejected.

Individual Independent Variables

As in previous regression runs, farm size remains important with the anticipated positive sign (Table 15). The positive sign indicates that larger farms adopted the machine earlier than the smaller farms. This result lends further support to evidence provided by the bivariate analysis in which the variable TIME was cross-tabulated with FSIZE (Table A-6). Gerhart (1975:43) found farm size to be significant in

Table 15. Results of Tobit analysis of earliness of use of the combine harvester, Muda Scheme, 1977-78 (dependent variable = TIME)[a]

Independent variable	Coefficient	Asymptotic "t"	Elasticity	
			Index	$E(y_3)$
CONST	-3.156	7.215		
FSIZE	0.074	4.858	1.207	0.620
OWN	0.015	0.104		
TEN	0.143	0.934		
PCL	0.121	1.622	0.652	0.335
SEX	-0.183	0.698		
ECON	0.265	2.262		
RCV	0.207	1.502		
NHBR	1.817	11.970		
AGE	-0.006	1.069	-0.773	-0.397
LABOR	-0.025	0.363	-0.160	-0.082
FUL	0.557	2.257		
SCH	-0.003	0.158	-0.039	-0.020
FAS	0.322	2.794		
FDA3	0.416	2.751		
FDA1	-0.043	0.291		

Log of likelihood function:

Unrestricted model = -556.89

Restricted model (with CONST only) = -745.71

$-2 \ell n \lambda = 377.64^{*} \sim \chi^2$, 15 d.f.

[a] NOTE: Number of limit observations = 623
Number of nonlimit observations = 235

* Significant at 0.005 level.

influencing earliness of HYV maize adoption in Kenya for his pooled data, but the variable was not significant in one of the zones studied for lack of variability. In the present study, the elasticity $E(y_3)$ shows that a 1 percent increase in farm size increased the expected number of seasons mechanized by 0.62 percent.[7]

As anticipated, and as found in the preceding analyses, the estimated coefficients for the perceived cost saving (ECON), technical superiority (RCV), neighbor's use (NHBR), Farmers' Association membership (FAS) and locality (FDA3) variables had positive signs with small standard errors. The standard errors of the remaining variables are about equal to or greater than their coefficients. The coefficients of the tenant (TEN) and owner (OWN) variables are both positive but have large standard errors. The results indicate that the early users did not come from any particular tenure group.

The PCL results suggest that the farmer with more parcels of land adopted the machine earlier, other things equal. The result, therefore, indicates that farmers with fragmented holdings were not at all the laggards in the adoption of the new harvesting technology in the Muda Scheme. Mechanization of smallholding agriculture, therefore, has not been hampered by the subdivision of holdings into "small uneconomic units." This is not to suggest that fragmentation is conducive to mechanization, but only to emphasize that the available evidence from the Muda area does suggest that mechanization of small paddy farms can be successfully implemented so long as neighboring farmers will cooperate with one another.

---

[7]The elasticity index is given by

$$\eta_{Ii} = \frac{\partial y^*}{\partial x_i} \cdot \frac{x_i}{y} = \beta_i \frac{x_i}{y}$$

(see Appendix A).

As in all previous formulations, the estimated coefficient of the "neighborhood" variable (NHBR) had a small standard error with the hypothesized positive sign. The positive sign suggests that farmers whose neighbors had used the machine used the combine harvester more times than those farmers whose neighbors had not used the machine. As the NHBR variable was intended to reflect the availability of the machine in an area, the results indicate that, once available, the technology will be readily received.

The estimated coefficients of AGE have been consistently negative with large standard errors in all previous regressions until the earliness-of-use run, when for the first time the coefficient had a small standard error. The negative sign means that the younger farmers compared to older farmers had a longer experience with mechanical harvesting in the Muda area. Bearing in mind the relatively short history of the combines in the Muda Scheme, the suggestion that younger farmers "tasted the salt" earlier than the older ones does not imply that the younger farmers had more farming experience than the older ones. The data only revealed the fact that with the combine harvester, which was introduced in the last four or five years, younger farmers were more likely to be the first ones to adopt the new technology.

The negative sign and large standard error of the estimated coefficient of LABOR provide further evidence in support of an earlier inference to the effect that the spread of the combine harvester has not forced labor from farms. Perhaps what is happening is that some family members are seeking employment on other farms, leaving their own farms to be tended by the household head, outside labor and the combine operator. It should be realized that family members are rarely paid on

a regular basis to work on the family plot, and selling their labor to other farms may be the only avenue to earn cash during the harvesting season.[8]

The results of the analysis showed that the full-time farmer adopted the combine harvester sooner than part-time farmers, other things equal. As suggested earlier, the part-time farmer might have made long-term commitments with friends and relatives to harvest his crop, while he attended to his main occupation.

The schooling variable again appeared to be of little consequence in influencing the time of adoption, i.e., better educated farmers (in terms of years of schooling) did not necessarily form the group of early adopters as far as the new harvesting technology in Muda is concerned.

The Tobit analysis of earliness of adoption provided further evidence of the underlying role of Farmers' Associations as an important agent of technological change in the Muda area. The results of the present analysis indicate that members of the FA's adopted mechanical harvesting sooner than nonmembers.

The positive sign of the estimated coefficient of the FDA3 variable indicates that farmers in FDA3 (Permatang Buluh locality) were generally earlier adopters than those in the excluded locality, i.e., FDA2.

Summary and Discussion of Results of the Multivariate Analyses

The results of the multivariate analyses are summarized in Table 16. In general, all the independent variables in the four equations

---

[8] One major complaint by farmers is that rural youths of today are no longer attracted to farm work and would rather stay idle than look for farm jobs.

Table 16. Summary of results of multivariate analyses of diffusion of the combine harvester, Muda Scheme, 1977-78

Independent variable	Choice (Logistic) ADOPT	Extent (Tobit) PER	Extent (Tobit) ARCOM	Earliness (Tobit) TIME
$FSIZE_2$	(+)[a]	(+)	(+)	(+)
$FSIZE^2$		(-)		
OWN	+	+	+	+
TEN	(+)	+	+	+
PCL	+	(+)	+	+
SEX	-	-	-	-
ECON	(+)	(+)	(+)	(+)
RCV	(+)	(+)	+	(+)
NHBR	(+)	(+)	(+)	(+)
AGE	-	-	-	-
LABOR	-	+	+	-
FUL	(+)	(+)	(+)	(+)
SCH	+	+	+	-
FAS	(+)	(+)	(+)	(+)
FDA3	(+)	(+)	(+)	(+)
FDA1	-	-	-	-
-2 $\ell n\ \lambda$		345.66	429.46	377.64
Degrees of freedom		16	15	15
Significance level		0.005	0.005	0.005

[a] Parentheses denote coefficients with standard errors that are less than the respective coefficients. Signs indicate signs of the regression coefficients. FSIZE-squared was included in the PER equation only.

behaved consistently in the sense that the signs of the estimated coefficients remained fairly stable. The only exceptions were LABOR and SCH. Farm size (FSIZE), perception of cost reduction (ECON), perception of higher rates of recovery of grain (RCV), combine use by a neighbor (NHBR), full-time farming (FUL), membership in a Farmers' Association (FAS) and location (FDA3) are the variables that were most closely associated with the decision to use the combine harvester and with the earliness and extent of this use.

Larger farms were more likely to use mechanized harvesting, adopted the technology earlier and used it to a greater extent, both in a relative and absolute sense, than smaller farms. Before concluding that the technology has, therefore, aggravated the distribution of income of farmers in the sense that large farms gained in relation to small farms, one should realize that there might not be any "economies of scale" involved in the adoption of the technology. The contract harvesting service is perfectly divisible and is equally accessible to large and small farms. The suggestion that farmers with large holdings tend to control more total resources than small ones and, hence, they produce more in excess of the proportion suggested by their number (Staub and Blase, 1974:587), may not be entirely correct in the case of Muda. The smaller farms may not have used the machine widely because there was less urgency in their case, or because a machine was not available at the right time.

Another interesting facet of the findings was that, ceteris paribus, members of the Farmers' Association had a longer experience with the new technology and used it more widely than nonmembers. The result is of interest because the contribution of the FA's to the spread of the

innovation has been largely indirect as the FA's (through MADA) had only 30 small combines (6-foot cutterbar) and the private contractors operated over 100 units of the large machines (14-foot cutterbar): yet, members of FA's used the machine sooner and more widely than the nonmembers. The FA's, therefore, had served as a very important communication channel and an "information exchange" agency which had indirectly encouraged mechanized harvesting.

Neither differences in tenure, degree of fragmentation of land holdings, sex of farm operator, age, nor years of schooling were closely associated with the substitution of the combine for hand harvesting. The fact that these variables have not hindered the use of this new technology is probably because of the kinship ties and willingness to cooperate among farmers and that the combines are hired and, thus, require no additional knowledge or skills on the part of the farmers.

The absence of a close association between differences in family labor availability and the substitution of the combine for hand labor was not expected. It may be that family members are reluctant to perform the harvesting tasks or that they work for hire on other farms. It does appear, however, that the use of combines is not an active factor in the creation of additional unemployment of family labor.

Policy Issues and Implications

This dissertation has dwelt at some length on the spread of the combine harvester in the smallholding economy of the Muda Irrigation Scheme. The approach taken was entirely micro, i.e., the goal was to determine what factors had been instrumental in farmer acceptance of the

new technology. It is appropriate now to turn to some policy issues and implications of the innovation to the Muda economy.

While farmer acceptance of the new technology was conditioned by several micro factors, the spread of the private contractual business has been encouraged by several macro factors. First, there existed a group of enterprising rural businessmen who saw the opportunity to share in the benefits of the Muda Scheme, a relatively new development project designed to uplift the living standards of small paddy farmers. The scarcity of labor, either in an absolute sense or because of a reluctance of the available labor to work on farms, created a favorable condition for investments in combine harvesters. The necessity to adhere to planting schedules specified by the Muda Scheme further enhanced the utility of the combine harvester in overcoming severe labor bottlenecks during the shortened harvesting seasons. Above all, the investments in combines in Muda indicated the favorable investment climate in Malaysia in general, which has been nurtured by a stable political structure that subscribes to the free enterprise system. Under this system a well developed financial institution has emerged to mobilize savings which ultimately become loanable funds to be invested in combine harvesters in the Muda Scheme.

The late Tun Abdul Razak bin Hussein, a former Prime Minister of Malaysia, stated that Malaysia had no policy on mechanization and that what the country had was a policy on agricultural development, and mechanization played its part within the programs of agricultural development (Southworth and Barnett, 1974:5). The statement is a good indicator of the free market economy that prevails in Muda and in Malaysia, which has encouraged the private contractual business.

The spread of the combines has no doubt resulted in a certain amount of redistribution of income from manual workers to combine owners, brokers and those employed to man the machines. By far the biggest beneficiary of the new technology, in monetary terms, appeared to be the group of machine owners who have invested heavily in these machines. The benefits accruing to this group of people are indeed "spillovers" from the construction of the Muda Irrigation Scheme--benefits which must not be dismissed in any discussion of the equity issue in a multiracial Malaysian society.

If the findings of this study are correct, only about one-fifth of Muda paddy lands are harvested by machine, which means that the potential scope for expansion is still wide, and no serious barriers to farmer acceptance appear to exist. In view of the so-called labor shortage in the area, any displacement of labor might have been only a temporary dislocation until the displaced labor could find other paddy farmers who wanted to harvest by hand. There were always farmers who were "forced" to use the traditional method since access of the combine is still rather limited. Furthermore, a badly lodged crop cannot be harvested by machines. Areas with potential danger of bogging too are shunned by the machine operators. These trouble spots will continue to be harvested by hand, very much to the displeasure of the workers who have complained that they were getting a "raw deal." In a sense their working conditions have deteriorated since they work on plots that have been skipped by the machines. To a certain extent, therefore, these workers have experienced a "welfare loss" even if there was no reduction in the number of days worked. To evaluate such a loss would, perhaps, require another study.

It is envisioned that complete mechanization could never be reached with the present state of the arts and the existing institutions. However, the acceptance of the new technique by farmers is expected to expand since factors that were found to influence adoption could easily be manipulated by policy. For example, as more farmers join the Farmers' Association, as more of them become aware of the economic and technical advantages of the machine, the new technology is expected to be used more extensively.

A land reform program which is aimed at consolidating land holdings and increasing the mean farm size and at the same time making land distribution more equitable (e.g., by reducing the variance of farm size), if implemented, is expected to accelerate the spread of the new technology since the evidence of the present study indicates that farm size was positively associated with adoption and levels of use of the machines. As level of mechanization increases, the distribution of income between the farming population of Muda and the nonfarming machine owners will continue to be more regressive against the farming population, unless the ownership is shared more equitably between the farming population and the small number of rural "industrialists." On the other hand, further mechanization does not have to await increases in ownership, reduction in tenancy nor reductions in land fragmentation as the evidence indicates that these conditions, to date, have not retarded the acceptance and use of combines.

Two objectives of the New Economic Policy (NEP) are poverty eradication and the restructuring of society. The Malaysian government, since the beginning of the Second Malaysia Plan, 1971-75, and following a bitter racial outburst in May, 1969, has advocated these objectives.

In view of these objectives, the Farmers' Association should evaluate the feasibility of direct ownership of the combines along the lines of the MADA-run Syarikat Perniagaan Peladang MADA (MADA Farmers' Business Enterprise) which is currently engaged in supplying machine spare parts to the FA's. MADA should also reappraise the economic profitability of the small combines in view of the numerous complaints heard from farmers about machine breakdowns and slowness in operation. The direct involvement of the FA's in the ownership of the combines, if operated efficiently, might divert at least some of the pure profits made from ownership of the combines from the already wealthy owner class to members of the FA's.[9] There is big business in mechanical rice harvesting in the Muda Scheme; the suggestion would definitely be in unison with the government's policy of encouraging the revival of the cooperative movement among the low-income farmers throughout the country. Hence, given the two-pronged objectives of the NEP, there appears to be a justification for moving towards cooperative ownership of strategic resources by the farmers themselves.

---

[9]The suggestion that there is pure profit in the combine hire business is supported, in part, by Rayarappan's findings (1979:57) that the private rate of return (IRR) in the combine business was 12.44 percent, compared with a lending rate of 9.5 percent charged by commercial banks. The risk involved in running the contract business does not appear to be great, and bearing in mind the tendency of contractors to understate the area harvested annually, the margin may be wider than that suggested by the figures quoted here. Furthermore, the business has not yet achieved equilibrium as new firms are making entry every harvesting season. Also, according to Jegatheesan (personal communication), the purchase price of the combines was fully recovered in three harvesting seasons. This short pay-back period strongly suggests the presence of pure profits, i.e., profits that are a surplus over and above necessary returns. Based on an expected annual area harvested of 927 acres by a 14-foot machine, Rayarappan (1979:60) calculated the annual net returns (returns to entrepreneurship) as M$11,490. In contrast, the average family income for a "labor abundant paddy farm" in Muda in 1972 was M$1,568 (Bell and Hazell, forthcoming).

CHAPTER V
SUMMARY AND CONCLUSIONS

Problem

The mid-sixties and the decade of the seventies will be recorded as the era of the green revolution in many less developed countries. During this period the world witnessed the emergence and spread of the new high yielding cereal varieties (HYV's) among third-world countries. The construction of irrigation facilities in these nations accelerated the diffusion of these HYV's as more and more land was put under double-cropping. Although the higher yields were achieved primarily from heavier applications of fertilizer and other modern inputs, including better management, the introduction of double-cropping has been associated with higher intensity of mechanization.

This study was concerned with the spread of a highly capital-intensive harvesting technology in the Muda Irrigation Scheme, a paddy farming area characterized by small farm holdings. The advent of this large machine on the small farm of Muda poses several interesting questions relating to factors that have contributed to the use of this sophisticated technology by peasant farmers in the largest paddy growing region of peninsular Malaysia.

Objectives

The primary objectives of this study were to explain farmers' choice of the new technology, relate the extent of use of mechanical harvesting to farm and farmer characteristics and investigate the nature of the diffusion process across farms through time. Other objectives were to describe the institutions that have emerged to support the innovation, identify the gainers and losers as a result of this technological change and examine government policies that have encouraged the spread of this new method in paddy harvesting. The results of this study should be of interest to several groups of people, such as students of technical change, government officials, economists, engineers and persons in the private sector who deal with agricultural machinery.

Data and Analytical Tools

Primary data collected by means of personal interviews with 858 farmers, 315 farm workers, 59 machine brokers and several machine owners form the bulk of the data used in this study. The interviews were conducted in late 1978 and early 1979 by use of structurally designed questionnaires. Farmers, farm workers and brokers were randomly selected from three of the 27 localities of the Muda area while a near-census of the machine owners was undertaken.

Both descriptive and analytical techniques were used in the study. The two major analytical tools used were the logit and the Tobit analyses. Logit analysis was used to explain a dichotomous dependent variable which assumed a value of 1 if the farmer used the combine harvester in the season under study and 0 if he did not. Based on the

knowledge gained from the literature review and also from the Muda area, independent variables included in the logit model are farm size, farmer's education, age, tenure status, a measure of the farm's fragmentation, farmer's perception of economic and technical advantage of the new technology, a measure of labor availability, a neighborhood variable indicating machine availability and a possible presence of a demonstration effect, farmer's full-time status, sex of farm operator and membership in a Farmers' Association.

The Tobit model was employed to analyze the "extent" and "earliness" of use of the new technology on individual farms. Within the Tobit framework three single-equation models were estimated with percentage of land mechanically harvested, actual land area mechanically harvested and the number of seasons the machine had been used, as dependent variables. The set of explanatory variables used was identical to that used in the logit model, with the exception that in the percentage-of-land-mechanized model, farm size was entered in a quadratic form based on a priori considerations. The Tobit model was deemed the most appropriate in explaining the extent and earliness of use of the combine harvester because the dependent variables to be explained were truncated at the zero level for over 70 percent of the farmers interviewed.

For both the logit and Tobit models, parameter estimates were obtained by maximum-likelihood procedures with the setting up of appropriate likelihood functions and maximizing these functions with respect to the parameters. The resulting normal equations were non-linear in the parameters and an iterative procedure was used to arrive at the estimates. The number of iterations varied among models and convergence was obtained in four to 16 iterations. The likelihood

ratio test was performed to test hypotheses about the overall relationship postulated.

Results

In each of the four limited dependent variable models estimated, the independent variables displayed a high degree of consistency in the sense that the signs of the regression coefficients remained stable from one equation to another, with only minor exceptions. The directions of influence were, in general, as hypothesized.

Farm size made a significant impact in all the four models and had positive estimated coefficients, implying that as farm size increased, other things equal, the probability of machine use in rice harvesting also increased. In addition, the results revealed that the larger farms not only used mechanized harvesting earlier than the smaller ones, but used the service to a greater degree both in a relative as well as an absolute sense, i.e., the larger farms achieved a higher percentage of land mechanized but attained a maximum percentage after a certain farm size was reached; and the larger farms also harvested a larger area by machines compared to the smaller farms.

Tenancy status generally was not consequential in the adoption and spread of the new mechanical technology. There was only fragmentary evidence in support of the suggestion that tenants were more innovative with regard to this mechanical technology, and that was provided by the results of the logistic regression. In all other equations, coefficients of the tenancy dummy variables had large standard errors.

The expectation that fragmentation might hinder the spread of the new technology did not materialize. The sex of the farmer did not

contribute toward explaining the observed variance in the dependent variables, either in the logit or the Tobit analyses. The age variable had negative estimated coefficients but large standard errors in all four models.

The two "psychological" variables, namely perception of economic advantage and perception of technical superiority of the machine vis-a-vis the traditional method, made substantial impact upon the probability of machine use, extent and earliness of use, except that the way farmers perceived the technical efficiency of the mechanical harvester was not significant in the actual-area-mechanized equation. The suggestion that farmers tended to emulate their neighbors appeared to be validated by the available evidence. The neighborhood variable had positive estimated coefficients with small standard errors in all four models.

For the labor variable, the signs were equally divided between positive and negative and the estimated coefficients had very large standard errors. Therefore, one could not conclude that mechanization was brought about by labor scarcity in the household, although it has been said time and again that mechanization was imperative in view of the regional labor scarcity.

Full-time farmers appeared to be earlier and more extensive users compared with part-time farmers, other things equal.

The schooling variable had the anticipated positive estimated coefficients in the choice and extent models but was negative in the earliness model and the standard errors were large in each case.

The results suggest that members of Farmers' Association were not only earlier users than the nonmembers but they also used the combine to a greater extent both in percentage terms and in absolute terms.

This conclusion was evident from the positive signs and small standard errors of the estimated coefficients of the FA membership dummy variable in all four models.

In addition to these farm and farmer characteristics, two regional dummy variables were also included in all equations to take into account the three "mechanization intensity" strata from which the sample localities were drawn. As it turned out, the FDA3 dummy variable had positive estimated coefficients with small standard errors in all four models, which implies that farmers in the Permatang Buluh locality were earlier users, in general, than those farmers in the excluded locality and used the machine to a greater extent.

This study set out to explain the behavior of a sample of small farmers in one of Malaysia's major rice growing areas with respect to acceptance of a highly capital-intensive, imported technology. The new technology appeared to have spread with differential rates depending on inherent as well as environmental attributes of the farmers. The study has, in a modest way, made a start in trying to improve the understanding of the mechanism of choice, and the judicious application, of a highly sophisticated and expensive technology in smallholding agriculture.

It is believed that there has been no serious displacement of labor in a situation of labor scarcity, although a "temporary dislocation" may have ensued; however, mechanization is imperative in situations of labor bottlenecks.

Suggestions for Further Research

A more definitive and quantitative appraisal of the welfare gains and losses of the various participants in this "technological drama" is needed in order to make recommendations as to how to transform part of the "spillovers" of a development project back into primary benefits which will accrue to the intended beneficiaries.

Another important area for further research pertains to the aggregate labor supply in the scheme. Related to the aggregate labor supply is the question of outmigration from the area. Is this outmigration likely to aggravate the labor scarcity in the years ahead? There is a need to make comparisons of labor participation between households that mechanize harvesting and those that do not in order to evaluate the impact of mechanization on household income and employment. Estimates of the future demand and supply of farm labor are needed in order that appropriate policies to accelerate or to constrain the extension of the use of combines may be formulated.

GLOSSARY

FA	:	Farmers' Association
FDA	:	Farmer Development Area, a subdivision of an irrigation district in the Muda Irrigation Scheme which is served by a Farmers' Association.
FDA1	:	Kodiang Farmer Development Area
FDA2	:	Titi Haji Idris Farmer Development Area
FDA3	:	Permatang Buluh Farmer Development Area
MADA	:	Muda Agricultural Development Authority, an agency set up by an Act of the Malaysian parliament in 1970 to coordinate agricultural development in the Muda Irrigation Scheme.
M$1.00	:	Malaysian unit of currency; one United States dollar is equivalent to 2.17 Malaysian dollars (Ringgit) at the present rate of exchange.
Relong	:	Unit of area measure used in the northern states of Perlis and Kedah, peninsular Malaysia; 1 relong = 0.711 acre.

APPENDICES

APPENDIX A
AN ELABORATION OF THE ANALYTICAL METHODS

Logistic Function

Suppose one has a random sample of size N. Without loss of generality, let the sample be ordered so that the first S individuals gave responses of $y_t = 1$ ($t = 1, \ldots, S$) and the remaining N - S individuals gave responses of $y_t = 0$ ($t = S + 1, \ldots, N$). In terms of the problem at hand, those responding $y_t = 1$ were users of the combine harvester and $y_t = 0$ were nonusers.

Since from the equation [3.2] in Chapter III $\Pr(y_t = 1) = [1 + \exp\{-\beta' x_t\}]^{-1}$ and $\Pr(y_t = 0) = 1 - \Pr(y_t = 1) = [\exp\{-\beta' x_t\}][1 + \exp\{-\beta' x_t\}]^{-1}$, we have the likelihood function, L, given by

$$
\begin{aligned}
[A.1] \qquad L &= [1 + \exp\{-\beta' x_1\}]^{-1} \ldots [1 + \exp\{-\beta' x_S\}]^{-1} \\
&\quad X[\exp\{-\beta' x_{S+1}\}][1 + \exp\{-\beta' x_{S+1}\}]^{-1} \\
&\quad \ldots [\exp\{-\beta' x_N\}][1 + \exp\{-\beta' x_N\}]^{-1} \\
&= \prod_{t=1}^{S} [1 + \exp\{-\beta' x_t\}]^{-1} \prod_{t=S+1}^{N} [\exp\{-\beta' x_t\}] \\
&\quad [1 + \exp\{-\beta' x_t\}]^{-1}
\end{aligned}
$$

Taking logs of both sides of [A.1] we have

$$
\begin{aligned}
[A.2] \qquad \ell n\, L &= -\sum_{t=1}^{S} \ell n\, [1 + \exp\{-\beta' x_t\}] - \sum_{t=S+1}^{N} \beta' x_t \\
&\quad - \sum_{t=S+1}^{N} \ell n\, [1 + \exp\{-\beta' x_t\}]
\end{aligned}
$$

The first order condition for $\ell n\, L$ to be at a maximum is

$$[A.3] \qquad \frac{d\,\ell n\, L}{d\beta} = 0$$

$$= \sum_{t=1}^{S} [x_t' \exp\{-\beta' x_t\}] [1 + \exp\{-\beta' x_t\}]^{-1} - \sum_{t=S+1}^{N} x_t$$

$$- \sum_{t=S+1}^{N} [-x_t' \exp\{-\beta' x_t\}] [1 + \exp\}-\beta' x_t\}]^{-1}$$

The value of β that satisfies this first order condition was found by an iterative procedure as explained in Nerlove and Press (1973:88-130).

To test hypotheses about the model, the likelihood ratio test may be used.[1] The likelihood ratio, λ, is the ratio of the value of the likelihood function maximized with the restricted model[2] to the value maximized with no restrictions except those implicit in the general model.

In large samples, such as the one used in the present study, the quantity $-2\ell n\lambda$ is distributed as a chi-square with as many degrees of freedom as there are independent restrictions embodied in the hypothesis being tested, relative to its alternative (Nerlove and Press, 1973:44).

Tobit Analysis

Preliminary examination of the data showed that, for a large number of respondents (72.6 percent), the dependent variables y_2, y_{20} and y_3 were concentrated at the lower limit of zero (the nonusers). For the users of the combine, y_2, y_{20} and y_3 took on positive values. A dependent variable which exhibits this characteristic is called a limited

---

[1] The test is unbiased and consistent (Maddala, 1977a:44).

[2] The restricted model is one in which the set of independent variables that enters the null hypothesis ($H_0: \beta_1 = \beta_2 = \ldots = \beta_h = 0$) is excluded from the estimated equation.

dependent variable (Tobin, 1958:24). The use of OLS to explain y_2, y_{20} or y_3 is inappropriate because, for very low values of the independent variable, the predicted value of y could become negative, which is clearly inadmissable. Tobin has put it succinctly:

> If only the value of the variable were to be explained, if there were no concentration of observations at a limit, multiple regression [OLS] would be an appropriate statistical technique. But when there is such concentration, the assumptions of the multiple regression model are not realized. According to that model, it should be possible to have values of the explanatory variables for which the expected value of the dependent variable is at its limiting value; and from this expected value, as from other expected values, it should be possible to have negative as well as positive deviations. (1958:25)

The method now prevailing to handle this kind of problem was first suggested by Tobin (1958:24-36) and has been aptly called Tobit analysis by Goldberger (1964:253). The technique has been widely discussed, used and improved upon by several other econometricians (e.g., Goldberger, 1964; Cragg, 1971; Johnson, 1972; Amemiya, 1973; Maddala, 1977a, 1977b; Fair, 1977; Dagenais, 1969, 1975).

The Tobit model may be stated as follows:[3]

$$[A.4] \qquad y_t = \beta' x_t + u_t \qquad \text{if } \beta' x_t + u_t > 0$$

$$= 0 \qquad \text{if } \beta' x_t + u_t \leq 0 \quad (t = 1, 2, \ldots, N)$$

where x_t is a K-component vector of values of the independent variables for the t^{th} observation, β is a K-component vector of unknown coefficients and u_t is a stochastic disturbance term independently distributed as $N(0, \sigma^2)$.

---

[3]See Amemiya (1973) and Fair (1977).

Without loss of generality, assume that the sample is partitioned into two groups, the first group consisting of individuals with $y_t > 0$ and the second group with $y_t = 0$. Let the first group consist of S individuals and the second group N - S individuals.

The likelihood function is given by

$$[A.5] \qquad L = \prod_{t=S+1}^{N} (1 - F_t) \prod_{t=1}^{S} (2\pi\sigma^2)^{-\frac{1}{2}} \exp\{-(1/2\sigma^2)(y_t - \beta' x_t)^2\}$$

where

$$[A.6] \qquad F_t = F(\beta' x_t, \sigma^2) = \int_{-\infty}^{\beta' x_t} (2\pi\sigma^2)^{-\frac{1}{2}} \exp\{-\tfrac{1}{2}(\lambda|\sigma)^2\}\, d\lambda$$

which is the normal cdf. Taking logs of both sides of [A.5] we have

$$[A.7] \qquad \ell n\, L = \sum_{t=S+1}^{N} \ell n\,(1 - F_t) - \frac{S}{2} \ell n\, \sigma^2 - \frac{S}{2} \ell n\, 2\pi - (2\sigma^2)^{-1} \sum_{t=1}^{S} (y_t - \beta' x_t)^2$$

The first order conditions (Fair, 1977:1724) for a maximum are

$$[A.8] \qquad \frac{\partial\, \ell n\, L}{\partial \beta} = \sum_{t=S+1}^{N} x_t\, f_t (1 - F_t)^{-1} + (\sigma^2)^{-1} \sum_{t=1}^{S} (y_t - \beta' x_t)\, x_t = 0$$

$$[A.9] \qquad \frac{\partial\, \ell n\, L}{\partial \sigma^2} = (2\sigma^2)^{-1} \sum_{t=S+1}^{N} \beta' x_t\, f_t (1 - F_t)^{-1} - (2\sigma^2)^{-1} S + (2\sigma^4)^{-1} \sum_{t=1}^{S} (y_t - \beta' x_t)^2 = 0$$

where

[A.10] $$f_t = f(\beta' x_t, \sigma^2) = (2\pi\sigma^2)^{-1} \exp\{-\tfrac{1}{2}(\beta' x_t|\sigma)^2\}$$

which is the normal density function.

Fair (1977:1724) has shown that

[A.11] $$\sigma^2 = \frac{1}{S} \sum_{t=1}^{S} (y_t - \beta' x_t)\, y_t = y'(y - X\beta)\, S^{-1}$$

and

[A.12] $$\beta = (X'X)^{-1} X'y - \sigma(X'X)^{-1} \bar{X}'\bar{\gamma}$$

where X' is K x S matrix, $\bar{X}'$ is K x (N - S) matrix and $\bar{\gamma}'$ is 1 x (N - S) vector. The first term on the RHS of [A.12] is the OLS estimate of β for the nonzero observations. Thus, equation [A.12] shows the relationship between the OLS estimates for the nonzero observations and the Tobit estimator (Fair, 1977:1724).

Hypothesis testing within the Tobit model was conducted along the same lines as the logit case, i.e., the likelihood ratio test (Tobin, 1958:28).

Apart from the interest in the signs and magnitudes of the Tobit coefficients, the present study was also interested in obtaining some measures of responsiveness of the dependent variable with respect to small changes in the independent variables. Economists speak of these measures as elasticities. Two elasticity concepts are relevant in the Tobit model, namely, the elasticity with respect to E(y) and the elasticity with respect to the "index" ($y_t^* = \beta' x_t$).

The expected value of y_t is given as[4]

[A.13] $$E(y_t) = F_t \beta' x_t + \sigma f_t$$

[4] See Maddala (1977b:223).

where F_t and f_t are as previously defined in [A.6] and [A.10], respectively, and $\beta' x_t = y_t^*$, the index. The elasticity of expected value with respect to the i^{th} independent variable is, therefore,

$$[A.14] \qquad \eta_{Ei} = \frac{\partial E(y_t) \cdot x_i}{\partial x_i \cdot E(y)} = \frac{F_t \beta_i x_i}{E(y_t | x_t)}$$

and the elasticity of index with respect to the i^{th} independent variable is

$$[A.15] \qquad \eta_{Ii} = \frac{\partial y_t^*}{\partial x_i} \cdot \frac{x_i}{y_t^*} = \beta_i \frac{x_i}{y_t}$$

APPENDIX B
DATA COLLECTION AND PROCESSING

The Questionnaires

Five sets of structured questionnaires were used for this study. These questionnaires were drawn up after several preliminary visits to the Muda Project area during which time the writer and an associate talked to farmers, workers, machine brokers, machine owners and government (MADA) officials. The questionnaires were all coded and structured for computer tabulation and analysis. Contents of these questionnaires are summarized below.

Schedule A--Machine Adoption by Farmers

Schedule A was rather short and could be completed within 25 minutes of interview. It was designed to seek information on whether or not the respondent had employed the service of the combine harvester in the last successful harvest, which invariably meant the second crop of 1977. The date of first use was also recorded. The schedule also sought to collect information on certain demographic, socio-economic and other ancillary variables which might serve as ex-ante explanatory variables with respect to the dependent variables.

Among the demographic variables are age, sex and family sixe. The socio-economic variables include, among others, schooling in years, farm size in the local unit relong, number of parcels operated and tenure status. The ancillary variables include the respondent's perceptions of cost advantage (if any) of mechanical harvesting and grain losses (or recovery) from the two methods. These two variables are "psychological" in nature and were treated as categorical or polytomous variables. Respondents were asked to state whether they thought that mechanical

harvesting was cheaper or dearer than traditional harvesting, or whether there was no difference between the two or whether they did not know. They were also asked whether any of their neighbors had used the machine in the previous season.

The four dependent variables of interest collected during Phase I included the dichotomous variable "ADOPT" (1 = yes, 0 = No), the proportion of farm which was mechanically harvested, the actual area mechanized, and the number of seasons the farmer had used the combine harvester.

Schedule A2--Second Farmer Interview

This schedule was administered to 293 farmers randomly selected from the initial sample of 858. It was designed to solicit the underlying reasons for using or not using the machine in the last season which were not included in Schedule A because of the desire to limit the length of each interview and to have a wider coverage. Multiple reasons were allowed for both groups of farmers. Some questions were posed to one or the other groups depending on their relevance. Some "psychological" questions were also asked. For example, all 293 respondents were asked if they had heard people say that paddy grains which were harvested by machine had a poor germination rate and if so whether they believed what they heard. Another question of the same nature was whether they had heard people say that mechanically harvested grain resulted in broken rice and, hence, poor eating quality.

Respondents were also asked to give, if they could, names and addresses of brokers with whom they were familiar. These names were later compiled to form the brokers sampling frame. Names and addresses

of hired workers were also collected during this interview for a similar purpose. The schedule also collected information on farm size operated, production and paddy varieties sown by farmers, modes of in-field transportation of paddy grains, etc. Because this schedule was slightly longer than Schedule A, it took about 45 minutes to interview a respondent.

Schedule B--Combine Harvester Owner

This machine owner schedule included technical (engineering) as well as economic questions. The first category included the technical specifications of the machine such as the engine capacity (horse-power), weight, cutter bar width and year of purchase. The economic questions focused on such items as the size of the labor force employed, wages paid, contract fee charged, commissions paid and sources of machine finance.

Schedule C--Worker Schedule

The aim of the farm worker schedule was to throw some light on the plight of the farm laborers (or hired workers) as a group. Hitherto very little information was available on this group of people. Schedule C asked respondents to state the various tasks they performed for wages in paddy production which ranged from land preparation to harvesting operations (reaping, threshing and paddy transportation). This schedule also enabled one to determine whether a respondent was a landless worker or not, and if he or she produced paddy, whether the combine harvester was used to harvest his or her paddy crop. As there were two distinct

groups of workers, namely reapers and threshers, certain questions were specifically directed toward one group or the other.

Demographic variables such as sex, marital status, age and family size were also included in this schedule. The number of days spent by workers in harvesting work during the previous season was also asked.

Schedule D--Machine Broker Schedule

This schedule was designed to characterize the machine brokers in the Muda Scheme. Hence, the usual demographic variables rank high on the list of variables included in this schedule. Other variables sought were the total acreage of paddy land arranged by the broker to be mechanically harvested in the last season, number of farmers contacted in the last season, size of paddy land farmed by the broker, problems faced as a commission agent and many others.

Fieldwork

First Phase

The enumerators employed in all phases of the survey work were recruited from the Muda Scheme area itself through the assistance of MADA Headquarters and the local Farmers' Association. The majority of the 22 enumerators recruited possessed the Malaysian Certificate of Education (MCE) or its equivalent, which is normally received after 13 years of schooling. The average age of these enumerators was 21 years with an average schooling of 10.6 years. The few enumerators who did not have the MCE were also taken in on the basis of previous working experience and maturity in dealing with farmers. However, no one

without the Lower Certificate of Education (LCE) or its equivalent was engaged to carry out the survey. As Schedule A was rather brief and straight-forward, it was felt that persons with the LCE and some survey experience and maturity could easily administer the schedule to farmers.

Being local residents and sons of paddy farmers themselves, the enumerators did not encounter serious problems of communication with the respondents. Training was given on the first day (October 28, 1978) at the MADA office in Alor Setar. The questionnaire was thoroughly reviewed during the training session and enumerators' queries were answered.

Actual interviews of farmers started in the Kodiang locality on the third day, as the second day was devoted to listing the Kodiang farmers. The questionnaires were field-edited the same evening they were turned in. Any discrepancies or inconsistencies in the answers were reconciled the following morning with the aid of the enumerator responsible. Phase I of the survey ended on November 15 in the Permatang Buluh locality.

Second Phase

Twenty-four enumerators signed up for this phase. Of these, four were assigned to interview the machine owners. Out of the four, three could speak the Hokkien (Chinese) dialect and were assigned to interview Chinese machine owners. Copies of a special letter of introduction prepared in Chinese were issued to the three enumerators to be passed on to the prospective respondents. It was later learned that the letter served its end rather well. The fourth machine enumerator was assigned to interview Malay owners. While all the second phase enumerators were local youths, 11 of them were students of the Malaysian Agricultural University; the others were carry-overs from the first phase fieldwork.

This phase of the fieldwork lasted from January 12 through January 27, 1979. At this time farmers had just completed harvesting their main-season crop and were waiting for water to prepare their land for the off-season.

Third Phase

The third and final phase of the fieldwork lasted from April 14 through April 28, 1979. Twenty-one enumerators, the majority of whom were "old hands," signed up for this phase. A total of 59 machine brokers and 315 hired farm workers were interviewed. Field-editing was done the evening the questionnaires were turned in, and problems encountered were resolved in the same manner as for previous phases. The questionnaires were coded in the field with the help of the research assistant.

Data Processing and Analysis

In each case the field-edited questionnaires were subjected to a second editing upon returning to the home base. During this office-editing, which was the sole domain of the writer, checks and double-checks were made of the coding done in the field. The office-edited schedules were then sent directly to a data processing firm in Kuala Lumpur for key punching and verifying, thereby by-passing the data-coding sheets. The procedure saved time and money.

The data were then tabulated and analyzed on the UNIVAC 1100/11 system at the University of Malaya Computer Center as well as on the AMDAHL 470 V/6-11 system at the University of Florida Computer Center.

The Statistical Package for the Social Sciences (SPSS) was used in the descriptive aspect of the data analysis. The logistic regression package developed by Nerlove and Press (1973) was used to estimate the logistic model of machine use and the Tobit package (code-named LIMDEP), developed by the Rand Corporation, was used to analyze the "extent" and "earliness" of use of the combine harvester by the Muda farmers.

APPENDIX C
LISTS OF VILLAGES SURVEYED

Villages (Kampong) Studied in FDA1
(Kodiang Locality)

	Mukim (Subdistrict)		Kampong (Village)
I.	AH	1.	Banggol Bongor
		2.	Melele
		3.	Permatang Kaka
		4.	Manggol Bongor
		5.	Lahar Kemeling
		6.	Megat Dewa
		7.	Kg. Paya Bukit Hantu
II.	PERING	1.	Paya, Bukit Hantu
		2.	Pulau
		3.	Kandis
		4.	Fida 2
		5.	Fida 4
		6.	Fida 5
		7.	Raja
		8.	Meribut
		9.	Pulau Si Putih
		10.	Si Putih
		11.	Kg. Pering
III.	KEPELU	1.	Kodiang Lama
		2.	Fida 3
		3.	Fida 3 Lama
		4.	Fida 4
		5.	Fida 5 Lama
		6.	Fida 5 Baru
		7.	Paya, Fida 1
		8.	Kodiang
IV.	KODIANG	1.	Fida 3, Jalan Sanglang

Villages (Kampong) Studied in FDA2
(Titi Haji Idris)

Mukim (Subdistrict)	Kampong (Village)
I. GUAR KEPAYANG	1. Tanah Merah Dalam
	2. Alor Pering
	3. Kerkau
	4. Tanah Merah
	5. Gulau
	6. Palas
II. TOBIAR	1. Sena/Balik Bukit
	2. Kepala Bukit
	3. Sungai Mati
	4. Banggol Keling
	5. Jelutung
	6. Kampong Sena
	7. Alor Berala
	8. Sungai Mati
	9. Gelong Gajah
	10. Penyarum
	11. Bukit Sekecung
	12. Tokla
	13. Kerangi
	14. Chekong
III. TAJAR	1. Alor Setol
	2. Alor Senibung
	3. Titi Haji Idris
	4. Alor Pak Ngah
IV. RAMBAI	1. Senara, Kubur Panjang
	2. Kubang Pisang
V. LESONG	1. Lubuk Keriang
	2. Banggol Senu
	3. Kuala Lanjut
	4. Permatang Limau
	5. Kuang Buang
	6. Gulau
	7. Nawa
VI. TUALANG	1. Alor Tebuan
	2. Alor Senibung

Villages (Kampong) Studied in FDA3
(Permatang Buluh)

	Mukim (Subdistrict)		Kampong (Village)
I.	SALA BESAR	1.	Permatang Buluh
		2.	Gelam 3
		3.	Gelam 2
		4.	Kuala Sg. Daun
		5.	Sungai Dedap
		6.	Sungai Daun Tengah
		7.	Sungai Daun Atas
		8.	Sungai Daun Ulu
		9.	Kubang Busuk
		10.	Permatang Tepi Laut
		11.	Bakong
		12.	Sungai Daun
II.	SUNGAI DAUN TENGAH		Sungai Daun Tengah
III.	SUNGAI DAUN	1.	Sungai Daun Ulu/Tengah
		2.	Kuala Sungai Daun
		3.	Permatang Kecil

APPENDIX D
GENERAL CHARACTERISTICS OF THE FARMER SAMPLE

Farm Size

Table A-1 shows the distribution of farms by size in the three localities studied. For the sample as a whole, slightly over half of the farmers interviewed operated no more than 3 acres of paddy land. All three localities displayed a distribition which was highly skewed to the left. The average farm size[1] for the entire sample of 858 farmers was 3.71 acres. This figure is slightly lower than the 4 acres often quoted by MADA in several of their reports.

Tenure

Table A-2 shows the distribution of farmers by tenure and locality. Over 45 percent of the farmers operated only their own land, while 31 percent were pure tenants, having no land of their own. The remaining 24 percent rented in some land in addition to operating their own paddy land. It appears that FDA2 has the highest concentration of full-owners (68.67 percent) while FDA3 has the highest concentration of tenants (48 percent). Part-ownership appears to be quite evenly distributed over the three FDAs (ranging from 20 to 30 percent).

Distribution of Farms by Size and Tenure

Table A-3 presents a cross-tabulation of farmers by tenure status by farm size. Nineteen percent of the farmers (or 168) were pure tenants operating no more than 3 acres of paddy land. Another 25.5 percent (or 219) were full-owners in this same farm size category.

---

[1] Farm size in this report refers to paddy land area operated by the farmer. It excludes land around the farmer's house, often devoted to vegetable growing or chicken raising for home use.

Table A-1. Number and percentage of farms by size and locality[a]

Farm size, acres[b]	Locality			Total
	Kodiang (FDA1)	Titi Haji Idris (FDA2)	Permatang Buluh (FDA3)	
< 3	124 (40.79)	160 (53.33)	151 (59.45)	435 (50.7)
3-5.99	111 (36.51)	104 (34.67)	78 (30.71)	293 (34.1)
6-8.99	47 (15.46)	29 (9.67)	11 (4.33)	87 (10.1)
9-11.99	19 (6.25)	4 (1.33)	5 (1.97)	28 (3.3)
12-14.99	3 (0.99)	3 (1.00)	5 (1.97)	11 (1.3)
15-20.99	0	0	3 (1.18)	3 (0.3)
21+	0	0	1 (0.39)	1 (0.1)
Total	304	300	254	858
Mean (acres)	4.25	3.43	3.39	3.71

[a] Numbers in parentheses are percentages.

[b] Overall mean = 3.71 acres;
Mean for users = 5.00 acres;
Mean for nonusers = 3.22 acres.

Table A-2. Tenure status of farmers by locality

Tenure	Locality			Total
	Kodiang (FDA1)	Titi Haji Idris (FDA2)	Permatang Buluh (FDA3)	
	Percent			
Owner	34.87	68.67	31.10	45.57
Tenant	35.53	11.33	48.03	30.77
Mixed	29.60	20.00	20.87	23.66
Total	100.00	100.00	100.00	100.00

Table A-3. Farm size by tenure status

Farm size class (acres)	Part-owner	Full tenant	Full owner	Total	
				Number	Percent
	---------- Number ----------				
< 3	48	168	219	435	50.7
3-5.99	94	71	128	293	34.1
6-8.99	41	17	29	87	10.1
9-11.99	18	4	6	28	3.3
12-14.99	5	2	4	11	1.3
15-20.99	0	2	1	3	0.3
21+	0	0	1	1	0.1
Total	206	264	388	858	100.0
Percent	24	31	45	100	

Table A-4 gives the percentage distribution of farms by size for each of the tenure groups. The model farm size class for the part-owners (or mixed tenure) is 3 to 6 acres (45.6 percent) while for the full-tenants and full-owners it is the 0 to 3 acres class with 63.6 percent and 56.4 percent of these categories, respectively. The classification of farm size by tenure group is statistically significant as seen from the Chi-square statistic of 110.61.

Farm Size Distribution for Adopters and Nonadopters

The survey also revealed that 27.4 percent of the farmers interviewed had used the combine harvester in the last successful harvesting season while the remainder (72.6 percent) used entirely the traditional method of harvesting. In terms of area, 21.4 percent of the paddy land in the sample was harvested mechanically.

Table A-5 gives the distribution of farms by size for these two categories of farmers. Although both distributions are negatively skewed, the modal class for the adopters is 3 to 6 acres (39.57 percent) whereas for the nonusers it is 0 to 3 acres (56.98 percent).

A simple calculation will show that 26.4 percent of farms using the machine are 6 acres or more in size whereas for the nonusers, only 10.9 percent belong to the 6 or more category. Furthermore, while 1.7 percent of adopters operated more than 15 acres of paddy land, no non-users operated more than 15 acres. These findings provide some *prima facie* evidence of the positive association between the adoption of the mechanical technology and farm size.

Table A-4. Percentage distribution of farm size and tenure

Tenure[a]	Acres							Total
	< 3	3-5.99	6-8.99	9-11.99	12-14.99	15-20.99	21+	
	Percent							
Owner	56.4	33.0	10.1	3.3	1.3	0.3	0.3	45.2
Tenant	63.6	26.9	6.4	1.5	0.8	0.8	0.0	30.8
Mixed	23.3	45.6	19.9	8.7	2.4	0.0	0.0	24.0
Total	50.7	34.1	10.1	3.3	1.3	0.3	0.1	100.0

[a] NOTE: Chi-square = 110.61 (12 d.f.) Significance = 0.0000

Table A-5. Distribution of farm size among users and nonusers of the combine harvester, 1977-78

Farm size (acres)	Users		Nonusers		Total
	Number	Percent	Number	Percent	
< 3	80	34.04	355	56.98	435
3-5.99	93	39.57	200	32.10	293
6-8.99	37	15.74	50	8.03	87
9-11.99	13	5.53	15	2.41	28
12-14.99	8	3.40	3	0.48	11
15-20.99	3	1.28	0		3
21+	1	0.43	0		1
Total	235	27.39	623	72.61	858

Experience with the Combine Harvester and Farm Size

The respondents were asked to state the number of seasons they had used the combine harvester to harvest their crop. A cross-tabulation of the number of seasons the farmer had combined his crop and the farm size operated is given in Table A-6.

Table A-6 shows that 24.1 percent of the farmers had used the combine harvester for the first time, 2.8 percent for the second time, 0.5 percent for the third time and a mere 0.2 percent for the fourth time.

The chi-square test, which is often used to test the null-hypothesis of no association between two nominal scale variables, gives a chi-square statistic of 390.58 (24 degrees of freedom) which is highly significant, statistically. The hypothesis of no association between farm size and the number of seasons the machine had been used is, therefore, rejected at a very high confidence level (e.g., 0.01).

Pearson's rank correlation coefficient which measures the degree of correlation between two ordinal scale variables, gives a value of 0.30 which suggests a weak positive correlation between farm size and number of seasons the machine had been used. This Pearson's R of 0.30 is statistically significant, suggesting that the bigger farms have had a longer experience with the combine harvester.

Date of First Adoption and Farm Size

The Phase I interview solicited information on the date the farmer had first adopted the machine to harvest his crop. The dates of first adoption are cross-tabulated with farm size in Table A-7. The earliest

Table A-6. Number of previous seasons farmers have used combine harvester by farm size[a]

Farm size class	Number of seasons					Total
	0	1	2	3	4	
	Number					
< 3	354	77	3	0	1	435
3-5.99	200	77	14	2	0	293
6-8.99	49	36	2	0	0	87
9-11.99	15	10	3	0	0	28
12-14.99	3	5	2	0	1	11
15-20.99	0	2	0	1	0	3
21+	0	0	0	1	0	1
Total	621[b]	207	24	4	2	858
(Percent)	(72.4)	(24.1)	(2.8)	(0.5)	(0.2)	(100.00)

[a] NOTE: Chi-square = 390.58 (24 d.f.) Significance = 0.0000
Pearson's R = 0.30 Significance = 0.0000

[b] Two farmers used the machine at least once before but they did not use it in 1977-78 harvesting seasons; hence, the discrepancy between the figure 621 above and 623 in Table A-5.

Table A-7. Date of first use of combine harvester by farm size[a]

Year and season	Acres							Total
	< 3	3-5.99	6-8.99	9-11.99	12-14.99	15-20.99	21+	
1974-II	0	0	0	0	0	1	0	1
1975-II[b]	0	0	0	0	1	0	0	1
1976-I	0	1	0	0	0	0	0	1
1976-II	1	6	0	0	1	0	1	9
1977-I	13	16	9	3	1	1	0	43
1977-II	66	67	28	10	5	1	0	177
1978-I	1	3	1	0	0	0	0	5
Never used	354	200	49	15	3	0	0	621
Total	435	293	87	28	11	3	1	858

[a] NOTE: Chi-square = 524.59 (42 d.f.) Significance = 0.0000
Pearson's R = -.29 Significance = 0.0000

[b] No farmer in the sample first adopted in 1975-I.

mechanical harvester user in the entire sample of 858 farmers was a farmer who operated a farm in the 15 to 21 acres size and he first adopted the machine during harvesting of the second season of the 1974 crop year.

This table also enables one to test the null hypothesis of no association between farm size class and date of first adoption. The chi-square statistic of 524.59 (42 degrees of freedom) is significant at the 0.01 level of probability. Pearson's R of -0.29 which is also statistically significant, shows that the larger the farm, the earlier it is likely to use the combine. The evidence derived from Table A-7 reinforces earlier evidence derived from Table A-6.

Characteristics of the Sample Based on the Independent Variables

Considerations discussed in Chapter III led to the identification of 13 variables as candidates for the explanatory variables in the multivariate analyses. Table A-8 gives some general characteristics of the 858 farmers interviewed in Phase I, based on these 13 variables. Table A-9 provides a comparison between users and nonusers based on the same set of characteristics.

Farm Size (FSIZE)

The smallest farm encountered was one-half relong in size (0.36 acre) in Kodiang locality (FDA1) and the largest was 40 relong (28.44 acres) in Permatang Buluh (FDA3). The mean farm size for the sample was 5.22 relong (3.71 acres). The mean farm size for users was 7.045 relong (5.0 acres), which is substantially higher than the 4.525 relong (3.21 acres) for nonusers.

Table A-8. Descriptive statistics of explanatory variables

Variable[a]	Mean	Range	
		Minimum	Maximum
FSIZE (relongs)	5.22	0.25	40.00
OWN (dummy)	0.45	0.0	1.00
TEN (dummy)	0.31	0.0	1.00
PCL	1.73	1.00	6.00
SEX (dummy)	0.06	0.0	1.00
ECON (dummy)	0.41	0.0	1.00
RCV (dummy)	0.17	0.0	1.00
NHBR (dummy)	0.54	0.0	1.00
AGE (years)	43.30	17.0	99.00
LABOR	2.09	0.0	5.34
FUL (dummy)	0.88	0.0	1.00
SCH (years)	3.97	0.0	15.00
FAS (dummy)	0.49	0.0	1.00
FDA3 (dummy)	0.29	0.0	1.00
FDA1 (dummy)	0.35	0.0	1.00

[a] KEY: FSIZE = Farm size
TEN = Full tenant
SEX = Sex
RCV = Perception of better grain recovery
NHBR = Neighborhood effect
LABOR = Labor availability
SCH = Schooling
FDA3 = Resident of FDA3
FDA1 = Resident of FDA1
OWN = Full owner
PCL = Fragmentation index
ECON = Perception of economic advantage
AGE = Age
FUL = Full-time status
FAS = Membership in Farmers' Association

Table A-9. Comparison of means of explanatory variables between users and nonusers

Variables[a]	Mean		
	Nonusers	Users	All
FSIZE (relongs)	4.525	7.045	5.22
OWN (dummy)	0.497	0.346	0.45
TEN (dummy)	0.292	0.350	0.31
PCL	1.65	1.96	1.73
SEX (dummy)	0.069	0.043	0.06
ECON (dummy)	0.330	0.641	0.41
RCV (dummy)	0.141	0.293	0.17
NHBR (dummy)	0.389	0.944	0.54
AGE (years)	43.490	42.910	43.30
LABOR	2.097	2.071	2.09
FUL (dummy)	0.853	0.966	0.88
SCH (years)	3.861	4.261	3.97
FAS (dummy)	0.438	0.630	0.49
FDA3 (dummy)	0.239	0.438	0.29
FDA1 (dummy	0.374	0.302	0.35

[a] KEY: FSIZE = Farm size
TEN = Full tenant
SEX = Sex
RCV = Perception of better grain recovery
NHBR = Neighborhood effect
LABOR = Labor availability
SCH = Schooling
FDA3 = Resident of FDA3
FDA1 = Resident of FDA1
OWN = Full owner
PCL = Fragmentation index
ECON = Perception of economic advantage
AGE = Age
FUL = Full-time status
FAS = Membership in Farmers' Association

Tenure Status (OWN, TEN)

Forty-five percent of all the farmers interviewed operated only their own paddy land. However, a larger proportion of the nonadopters (49.7 percent) operated only their own land while 34.6 percent of the adopters operated only their own land.

Slightly over 29 percent of the nonadopters were strictly tenants compared with 35 percent of the adopters who belonged to the pure-tenant class (Table A-9). Thus, 21.1 percent of the nonadopters and 30.4 percent of the adopters were of mixed tenure.

Fragmentation Index (PCL)

The number of parcels of paddy land operated by farmers ranged from one to six. The mean was 1.73. The mean for adopters was 1.97 and for nonadopters 1.64.

Sex of Respondents (SEX)

It was found that about 6 percent of the heads of households interviewed were women. They were either divorced or widowed. Among the nonadopters, 6.9 percent were women while in the adopter group 4.3 percent were women (Table A-9).

Perception of Economic Advantage (ECON)

Table A-8 shows that 41 percent of the respondents actually believed it was cheaper to harvest paddy with the combine harvester. The proportion of users and nonusers who perceived the economic advantage of using the machine was 64.1 percent and 33.0 percent, respectively.

Table A-10 gives a breakdown of actual responses to the question of whether the combine harvester was cheaper to use than manual harvesting. It is evident that a much larger proportion (26.8 percent) of the non-users than the users (0.43 percent) did not really know (and probably did not want to commit themselves) about the relative economic advantage of the two techniques. About equal proportions of both categories of farmers (28.4 and 28.9 percent) did not see any difference in the relative cost of the two methods. Only 6.81 percent of the users thought that the traditional method of harvesting cost less in their own situations and yet chose the more expensive method, perhaps because of the time-saving element of the combine harvester.

The cost of harvesting paddy by a mechanical harvester at present ranges from M$45 to M$60 per relong (or M$63.29 to M$84.39 per acre) while to harvest by hired labor it may cost anywhere from M$50 to M$70 per relong (M$70.32 to M$98.45 per acre). On top of this, the farmer often has to add expenses for workers' meals, coffee breaks and, in the case of migrant workers, sleeping quarters. Additional expenses and labor are also incurred in transporting the harvest from the threshing area to the bunds. This in-field transportation is provided free by the combine harvester which gives it an edge over the traditional method.[2]

The cross-tabulation in Table A-10 gives a chi-square of 103.55 (3 degrees of freedom) which is statistically significant at better than the 0.01 level. Thus, the null hypothesis of no association between the response category and the farmer category is rejected. A test of correlation is inadmissible in this case since both variables are only measured at the nominal level.

---

[2]See also pages 185-190 for an economic comparison of the two methods.

Table A-10. Farmers' perception of relative cost of combine harvesting compared with old method[a]

Response	Users		Nonusers		Total	
	Number	Percent	Number	Percent	Number	Percent
Combine costs less (ECON = 1)	150	63.83	206	33.07	356	41.49
Old method costs less (ECON = 0)	16	6.81	73	11.72	89	10.37
No difference between them (ECON = 0)	68	28.94	177	28.41	245	28.55
Did not know (ECON = 0)	1	0.43	167	26.81	168	19.58
Total	235		623		858	

[a] NOTE: Chi-square = 103.55 (3 d.f.) Significance = 0.0000

Grain Recovery (RCV)

Tables A-8 and A-9 also show that only 17 percent of the farmers interviewed believed that grain recovery of the combine harvester was superior to traditional methods. The corresponding figures for users and nonusers were 29.3 and 14.1 percent, respectively.

Grain losses by the combine harvester can originate from

(a) Failure of the cutting mechanism to cut all the grain;

(b) Failure of the threshing mechanism to remove the seed from the head or pod;

(c) Failure of the separating mechanism to separate the seed from the straw and

(d) Cracking of the seed in the threshing process or the seed being blown away in the cleaning process (Phipps, 1967:541).

On the other hand, shattering losses in manual harvesting may originate from several stages of the harvesting operation--during cutting and transportation to the threshing area, during threshing and also during winnowing. Inexperienced workers may not thresh the crop completely, often leaving grains intact on the panicle.

Admittedly responses to this kind of inquiry are beset with subjective evaluation by the respondents as to the true situation. Still, over a wide range of respondents, one expects the answers to be generally consistent with reality.

Table A-11 gives a detailed analysis of responses by both users and nonusers to the question of grain recovery from both techniques. A large proportion of the nonusers (26 percent) did not want to commit themselves on this issue (fourth row, fourth column, Table A-11),

Table A-11. Perception of grain loss by users and nonusers[a]

Response	Users		Nonusers		Total	
	Number	Percent	Number	Percent	Number	Percent
Less loss by combine (RCV = 1)	57	24.26	88	14.13	145	16.90
Less loss by old method (RCV = 0)	33	14.04	147	23.60	180	20.98
No difference between them (RCV = 0)	140	59.57	226	36.28	366	42.66
Did not know (RCV = 0)	5	2.13	162	26.00	167	19.46
Total	235		623		858	

[a] NOTE: Chi-square = 89.47 (3 d.f.) Significance = 0.0000

whereas only 2.13 percent of the users gave this kind of response. The majority of the users (59.57 percent) believed there was no difference in the recovery rate of the two techniques. They constituted 16.3 percent of the sample of 858 farmers. About 14.0 percent of the adopters (3.85 percent of the entire sample) thought that the old method was superior in grain recovery.

On the whole, about 43 percent of the respondents believed that there was essentially no difference between the two methods. Those who believed in the superiority of the combine were very much in the minority (16.9 percent) (Table A-11).

The null hypothesis of no association between these response categories and the categories of respondents was rejected at the 0.01 level of probability based on the chi-square of 89.4 (3 degrees of freedom).

Neighborhood Effect (NHBR)

Fifty-four percent of the respondents reported that their neighbors had used the combine harvester in the last successful harvesting season (Table A-8). Of these, 47.9 percent used the machine themselves, and of those who reported that neighbors did not use the machine only 3.3 percent used the machine (Table A-12). The substantial difference in these proportions provides evidence of the importance of the NHBR variable in influencing the adoption of mechanical harvesting in the Muda area.

Table A-12. Cross-tabulation of combine users and nonusers by neighboring users and nonusers

Farmer category	NHBR (Did neighbor use machine?)				Total	
	Yes		No			
	Number	Percent	Number	Percent	Number	Percent
User	222	47.9	13	3.3	235	27.4
Nonuser	241	52.1	382	96.7	623	72.6
Total	463	54.0	395	46	858	100.0

Corrected chi-square = 211.50 (1 d.f.) Significance = 0.000

Age of Respondents (AGE)

The youngest respondent in the sample was a 17-year-old farmer while the eldest was 99 years old. The mean age of the farmers was 43.3 years (Table A-8). Nonusers were slightly older (mean age = 43.49 years) than the users (mean age = 42.91 years) but the difference appears to be quite negligible. Table A-13 gives the distribution of farmers by age within locality.

Labor Availability (LABOR)

Family labor availability was measured in adult equivalents of full-time family members available to participate in harvesting work. It was immaterial whether they did actually participate or not. The measure on this variable ranged from 0 to 5.34 with a mean of 2.09 adult equivalents (Table A-8). The nonusers had a slightly higher mean (2.10) the the users (2.07).

Full-time Farmers (FUL)

Eighty-eight percent of the farmers interviewed may be considered as full-time farmers. For the users, 96.6 percent were full-time paddy farmers, while in the case of nonusers, 85.3 percent were full-time farmers (Table A-9).

Membership in Farmers' Association

Of the 858 farmers in the sample, 421 (49 percent) were members of their local FA's, out of which 148 (35 percent) used the machine to harvest their crop. Of the 437 nonmembers, only 87 (20 percent) used

Table A-13. Percentage distribution of farmers by age within locality

Locality	Years							Total
	20 and less	21-30	31-40	41-50	51-60	61-70	Over 70	
	Percent							
Kodiang	1.0	19.1	25.7	22.0	20.4	9.9	2.0	100.00
Titi Haji Idris	0.7	17.7	29.3	29.3	13.3	6.0	3.7	100.00
Permatang Buluh	0.4	18.1	25.6	29.5	18.1	6.3	2.0	100.00
Sample N = 858	0.7	18.3	26.9	26.8	17.2	7.5	2.6	100.00

mechanical harvesting. Thus, there appears to be strong evidence of association between membership in a Farmers' Association and the adoption of the new mechanical harvesting technology in the Muda Scheme.

Schooling (SCH)

The average length of school attendance for the sample was 3.97 years. The users had a slightly longer school attendance (4.26 years) than the nonusers (3.86 years) (Table A-9).

Reasons For and Against the Choice of the Combine Harvester

In Phase II of the survey, machine users were asked to give reasons for their choice of the machine in harvesting while the nonusers were asked why they did not harvest by machine.

Tables A-14 and A-15 give the results of this inquiry for the users and nonusers, respectively. Nearly 84 percent of the 136 users indicated the great speed of the machine as their reason for employing it. This was the most popular reason in all three FDAs. A second reason (40.4 percent) was the difficulty of finding manual labor to do the work. A third reason closely related to the second was "shortage of manpower" on the farm.

For the nonusers, the most popular answer (49 percent) was that the farm was "too small" to justify mechanical harvesting. The second most important reason for not adopting the machine (43.3 percent) was the fact that the crop did not ripen "evenly"--meaning that it either ripened too early or too late in relation to neighboring fields. This involves the questions of accessibility and economics. If a plot of

Table A-14. Reasons given by machine users for using combine harvester by locality

	Reasons[a]	Locality			All
		FDA1	FDA2	FDA3	
		Percent			
1.	Shortage of manpower	30.8	39.7	43.6	38.27
2.	My farm is large or too far away	7.7	13.8	17.2	13.03
3.	Machine is faster	82.1	89.7	76.9	83.85
4.	Hard to find workers	33.3	55.2	25.6	40.43
5.	Labor is too expensive	17.9	17.2	20.5	18.35
6.	Crop ripened with others	33.3	27.6	35.9	31.61
7.	Machine is cheaper	51.3	8.6	38.5	29.42
8.	Must provide food if manual workers are used	5.1	1.7	5.1	3.65
9.	Crop wasn't that good; and machine recovers all	7.7	---	---	2.21
10.	As a trial run only	5.1	---	5.1	2.93
11.	Very convenient; harvest is stacked at one place	5.1	5.2	---	3.68
12.	Better price of paddy if harvested by machine	---	---	2.6	0.75
13.	I am a machine broker	---	---	5.1	1.46
14.	Paddy requires no cleaning	2.6	---	5.1	2.21
15.	More output	7.7	---	---	2.21
16.	More free time	---	1.7	2.6	1.47
17.	Not specified	---	3.4	2.6	2.20
		$n_1 = 39$	$n_2 = 58$	$n_3 = 39$	$N_1 = 136$

[a] Multiple answers were allowed in the survey instrument.

Table A-15. Reasons given by nonusers for not mechanizing harvesting by locality

	Reasons[a]	Locality			All
		FDA1	FDA2	FDA3	
		Percent			
1.	Farm too small	55.6	44.2	46.7	49.08
2.	Plots too deep for machine	7.4	11.6	26.7	15.92
3.	No machine in my area	16.7	60.5	11.7	26.78
4.	I had enough workers	24.1	37.2	45.0	35.67
5.	Uneven ripening	59.3	25.6	41.7	43.34
6.	Machine spoils the land	7.4	18.6	25.0	17.19
7.	Paddy had been attacked by pests	9.3	4.7	1.7	5.14
8.	Water was too deep	1.9	4.7	---	0.78
9.	Land was not accessible	5.6	---	5.0	3.84
10.	Had agreed to give to planting labor	3.8	---	---	1.31
11.	Used own labor to minimize cost	1.9	2.3	---	1.28
12.	Bad lodging in my crop	1.9	---	3.4	1.95
13.	Plot was too small for machine	1.9	---	---	0.65
14.	Too much grain loss	1.9	2.3	---	1.28
15.	Wanted to wait and see first	1.9	---	1.7	1.30
16.	Too many people chasing after too few machines	---	4.7	---	1.29
17.	Did not know of any broker	1.9	---	1.7	1.30
18.	Wanted to give some jobs to fellow-villagers	---	2.3	1.7	1.28
19	MADA's machine could not be used	1.9	---	1.7	1.30
		$n_1 = 54$	$n_2 = 43$	$n_3 = 60$	$N_2 = 157$

[a] Multiple answers were allowed in the survey instrument.

paddy ripens too early, there is probably no way in which a combine can get to it. If it ripens too late, it will not be economical for a combine to return and harvest it. Hence, the farmer who is out of schedule will often not be able to harvest mechanically. Thus, there appears to be an externality issue involved in the use of combines in the Muda Scheme.

Table A-16 gives a list of reasons why machine users did not mechanize the harvest of their entire crop. The most frequent reason (33 percent) was that their crops did not ripen "evenly." The "uneven" ripening was mainly due to uneven sowing and uneven planting dates among neighboring farmers. These differences were, in turn, due to slightly different dates of water availability. The kind of irrigation system used in Muda does not allow individual farmers to exercise freedom in the management of the water on their holdings. Even if water were made available simultaneously to two neighboring farmers, there was no guarantee that both farmers would sow and transplant their crops at the same time. With regard to the uneven ripening, Len states

> The uneven ripening of the [paddy] crop in various parts of the area does pose a [problem]. The planting time will have to be uniform if combine harvesting is to be carried out [economically]. (1967:1)

Average Yields

Table A-17 gives the mean yield of paddy in pounds per acre for users and nonusers of the combine harvester as reported by the farmers in Phase II interviews. The mean yield was obtained by taking the average of each respondent's yield per acre and, therefore, was not a weighted average. The only locality to show a statistically significant

Table A-16. Reasons for not mechanizing the entire crop by users

	Reasons[a]	Number of farmers	Percent
1.	Ripening not even	45	33.1
2.	Purposely wanted to harvest manually	23	16.9
3.	Some part was too deep	17	12.1
4.	Lodging of crop	15	11.0
5.	Machines refused to harvest because too little	5	3.7
6.	Machine came too late	4	2.9
7.	Wanted to harvest for seed	3	2.2
8.	No access	3	2.2
9.	Too much water in plot	2	1.5
10.	Children and in-laws came to help	1	0.7
11.	Pity the villagers	1	0.7
12.	Machine left area too early	1	0.7
		N_1 = 136	100.0

[a] Multiple answers were allowed in the survey instrument.

Table A-17. Average yields reported by users and nonusers of combine harvester by locality

Locality	Yield		Pooled variance estimate		
	User	Nonuser	t-value	d.f.	2-tail probability
	----- lbs/acre -----				
Kodiang	3001.5	2680.5	1.88	91	.063*
Titi Haji Idris	3287.9	3205.9	.43	99	.671ns
Permatang Buluh	3423.8	3362.5	.41	97	.679ns
All	3244.8	3085	1.57	291	.116ns

* Significant at 10 percent level.
ns = not significant.

difference in the yield between mechanized and nonmechanized farm (disregarding level of mechanization) was Kodiang, where the difference was significant at better than the 10 percent level. The overall yield for the 293 farms interviewed lies between 3085 and 3245 lbs per acre. A survey of 382 farmers in a pilot project conducted by MADA (1970d:5) gave a mean yield of 3329 lbs per acre. The average yield for the Muda Scheme in 1970 was said to be 3080 lbs per acre (MADA, 1970c:4), although the Bahagia variety, which was recommended by the Department of Agriculture, had a yield potential of 4480 lbs per acre. Farmers in this study reported using two major varieties, locally known as Anak Dara and Seribu Gantang.

APPENDIX E
BROKERS, WORKERS AND THE INSTITUTIONAL STRUCTURE

The purpose of this Appendix is to provide a general picture of the institutional arrangements that have emerged to support the new harvesting technology in Muda, to identify and characterize the major parties involved and to assess the gains accrued to, and losses incurred by, the various parties. Far from being a rigorous assessment of the situation, this section is merely exploratory in nature and not meant to provide final and definite answers on social gains and losses along the lines of mathematical welfare economics.

The Brokerage System

The spread of the service of the mechanical harvester in Muda has been facilitated to a large extent by the brokerage system in which commission agents make arrangements for the machine to harvest farmers' paddy.[1] About 67 percent of the farmers who reported using the machine, in Phase II interviews, made their arrangements through brokers (Table A-18).

Of the farmers that did not use the machine, nearly 70 percent did not know of any broker in their villages (Table A-19). This result tends to suggest that had they known a broker, many of these farmers might have used the combine. Only 1.5 percent of the users did not know a broker.

Combine harvester owners must find it advantageous to use brokers to make contacts with farmers. First, most of the machine owners are ethnic Chinese (Table A-20) while 95 percent of the paddy farmers are Malays. By appointing local Malay brokers, the machine owners have

[1] Rayarappan (1979:6) reports that the private contractual system in tractor cultivation, which also uses brokers, is now 18 years old.

Table A-18. Method of contacting machine operator by users

Method	Respondents	
	Number	Percent
1. Through broker	91	66.9
2. Contacted the driver or machine owner at his house/shop	13	9.6
3. Arranged it while machine was doing harvesting in my village	20	14.7
4. Other methods	10	7.4
5. No information	2	1.5
Total	136	100.0

Table A-19. Distance to nearest broker from farmer's house

Distance in miles	User	Nonuser
	--------- Percent ---------	
Less than 1	33.8	14.6
1-2	25.7	12.7
2.1-3	11.8	1.3
3.1-4	3.7	0.6
4.1-5	3.7	0.6
More than 5	12.5	0.6
Did not know a broker	1.5	68.8
Distance not known	2.2	---
MADA machine	3.7	---
No information	1.5	0.6
Total	100.0	100.0
Sample size	N_1 = 137	N_2 = 157

Table A-20. Distribution of brokers by ethnic group of principal and locality

Locality	Ethnic group of principal				
	MADA	Chinese	Malay	Chinese and Malay	Total
	Count				
Kodiang	1 (3.6)[a]	23 (82.1)	3 (10.7)	1 (3.6)	28 (100)
Titi Haji Idris	3 (14.3)	16 (76.2)	2 (9.5)	0 ---	21 (100)
Permatang Buluh	2 (20.0)	8 (80.0)	0 ---	0 ---	10 (100)
Total	6	47	5	1	59
Percent	10.2	79.7	8.5	1.7	100

[a] Number in parentheses denote row percentages.

overcome one social obstacle in their quest to win farmers' confidence and patronage. Second, the use of brokers avoids machine down time which is very costly as capital investment is in the order of M$170,000 and above and, since the harvesting season is short, any down time means foregone business. Third, the use of these commission agents takes away the toil of collecting fees from the farmers by machine owners.[2] The fees are paid in cash rather than in kind because the collection of fees in kind from 400 to 500 farmers in a season would be quite "messy." Fourth, the broker is responsible for the security of the machine in the village at night as the machine is seldom taken home. Table A-21 gives the duties of brokers.

For these services, the brokers receive a commission based on the acreage harvested. The survey of the brokers showed that machine owners paid brokers from M$2 to M$10 per relong (M$2.80 to M$14 per acre) for their services. In the season of the study, the brokers contacted an average of 57 paddy farmers each for contract harvesting. On the average, a broker earned about M$760 in the survey season. The average broker arranged to harvest about 124 acres of paddy land during the season. According to these brokers, farmers were charged from M$63 to M$84 per acre harvested by machine. The brokers themselves were charged anywhere from nothing to M$84 per acre to have their crop harvested. Those brokers who did not have to pay for the machine service were certainly enjoying an important fringe benefit.

As a beneficiary of this technological change, the brokers form an interesting group worthy of closer examination. The average broker is

---

[2]The major problem reported by brokers was collection of fees (see Table A-22).

Table A-21. Duties of the broker

Duties reported	Locality			Total
	Kodiang	Titi Haji Idris	Permatang Buluh	
	Number			
Guards machine at night	11	13	5	29
Deliver fuel to driver	4	5	2	11
Prepare driver's meal	4	4	2	10
Inform driver of deep areas	2	3	2	7
Inform MADA of break-down[a]	0	0	1	1
Get permission to pass through	1	0	0	1

[a] This refers to MADA brokers only.

below 40 years old (mean age is 39.5 years), with mean formal school attendance (secular education) of 4.4 years which is higher than the total schooling (secular and religious) of the average farmer in the sample (4.0 years). These brokers had a mean family size of 6.7 with 5.8 dependents. The average length of local residence of the brokers was 30.3 years, which implies that they were well known among the villagers and to the machine owners. To be well known is very important, as brokers must be trusted both by farmers and by machine owners.

Generally, the brokers were paddy farmers with slightly larger than average farms. The average farm size of the brokers was 5.5 acres, which is higher than the 4-acre average of Muda farmers as a whole. The average broker owned about 3.2 acres paddy land.

Tables A-22 to A-24 give some interesting characteristics of the brokers, as a group, who have participated in the diffusion of the new harvesting technology in Muda. Over two-thirds of the brokers were involved in one kind of social organization or another[3] (Table A-22). There is reason to believe that the majority of these harvester brokers were also tractor brokers during the planting season.[4]

Farm Labor in Manual Harvesting

One of the concerns of economists and policy makers, with regard to the consequences of mechanization, is labor displacement with no subsequent employment opportunities, which would lead to what Karl Marx

---

[3]Organizations included were FA's, political parties, khairat kematian (which makes arrangements and pays for funeral expenses), syarikat pinggan mangkuk (kitchenware-lending society--useful during feasts and ceremonies) and rice-milling cooperatives.

[4]The information was not sought through an oversight, but was conveyed through casual conversation with farmers.

Table A-22. Social characteristics of brokers

	Percent of total sample[a]
1. Marital status:	
Married	93.20
Single	6.8
2. Head of household:	
Yes	89.83
No	10.17
3. Born in this village:	
Yes	59.30
No	40.70
4. Born in this FDA:	
Yes	83.05
No	16.95
5. Social participation:[b]	
None	32.23
One activity	25.40
Two activities	22.00
Three activities	10.20
Four or more	10.17
One or more	67.77
6. Plant paddy:	
Yes	96.6
No	3.4
7. Used machine to harvest:	
Yes	88.1
No	11.9
8. Problems as brokers:	
Collection of fees	50.8
Other problem	13.6
None	35.6

[a] N = 59.

[b] Membership and/or leadership in local organizations.

Table A-23. Other socio-economic characteristics of brokers

	Characteristic	Mean	Minimum	Maximum
1.	Age (years)	39.49	18.0	56.0
2.	Formal schooling (years)	4.39	0.0	12.0
3.	Religious school (years)	1.39	0.0	8.0
4.	Family size	6.71	2.0	14.0
5.	Number of dependents	5.83	0.0	11.0
6.	Length of local residence (years)	30.29	3.0	56.0
7.	Social participation index	1.46	0.0	6.0
8.	Distance to nearest primary school (miles)	1.50	0.33	6.0
9.	Number of seasons as broker	2.49	1.0	11.0
10.	Farm size (acres)	5.53	0.0	24.89
11.	Own land (acres)	3.18	0.0	17.78
12.	Fee paid by broker to harvest own paddy (M$ per acre)[a]	50.30	0.0	84.39
13.	Fee charged to farmers to harvest paddy (M$ per acre)[a]	78.31	63.29	84.39
14.	Commission received (M$ per acre)	7.00	2.80	14.00
15.	Total area arranged for machine harvest last season (acres)	123.90	21.33	497.70
16.	Number of farmers contacted last season	56.68	8	400
17.	Total commission earned last season (M$)	762.63	75.00	2500.00

[a] The figure is based on data given in M$ per relong (1 relong = 0.711 acre).

Table A-24. Number and percentage of brokers reporting intention of buying a combine, by locality

	Not planning to buy	Undecided	Planning to buy	Not specified
Kodiang	12 (42.9)[a]	8 (28.6)	8 (28.6)	0 ---
Titi Haji Idris	15 (71.4)	2 (9.5)	4 (19.0)	0 ---
Permatang Buluh	7 (70.0)	1 (10.0)	0 ---	2 (20.0)
Total	34 (57.6)	11 (18.6)	12 (20.3)	2 (3.4)

[a] Numbers in parentheses indicate percentages.

refers to as the reserve army of the unemployed. Labor displacement alone is not a sufficient ground for one to be concerned about mechanization. In a situation of surplus agricultural labor, labor displacement by mechanization may aggravate the unemployment problem in the affected area. Under this condition, mechanization may have undesirable effects. Nearly 30 years ago, Berwick (1951:207), in arguing the case for mechanization in paddy production, asserted that

> Most of the inhabitants of Malaya earned their living, directly or indirectly, from the export of tin, rubber or other cash crops, and there is not a large surplus of labor ready to march into new areas and grow more paddy.

Ooi observes

> Because of the hard work involved, the higher earnings of other occupations, the attractions and amenities of town life, many of the younger Malays are drifting from the paddy areas and rural kampong in search of other work . . . Speedy mechanical harvesting would seem to offer great scope as a means of indirectly increasing paddy production by lessening the chances of an untimely rainstorm ruining part of the ripened crop. (1963:226)

> The problem of labor shortage in Muda is[5]
>
> . . . manifested by the large number of hired labor who commute to Muda annually from Southern Thailand and Kelantan [in northeastern sector] to take up these job opportunities. In 1968/69, 10,145 Kelantanese and 5,926 Patanis [Southern Thais] were reported to have travelled to Muda for harvesting jobs. This annual migration has, however, dwindled for various reasons and has brought back the labor shortage problem. (Afifuddin et al., 1974:2)

One might feel concerned about the adverse effect mechanization has on the 4,300 landless, nontenant, paddy farm workers' families (Jegatheesan, 1977:58) in the Muda area. They constitute about 4 percent of the population of Muda. However, even for these people,

---

[5]The reduced migration flow from Kelantan and Thailand may be due to the implementation of double-cropping in Kelantan (Kemubu Scheme) and tighter immigration controls at the border towns of Padang Besar and Changloon, for security reasons.

mechanization can only be judged bad if alternative employment is closed completely after mechanization.

The present study was not designed to trace what happened to the displaced labor arising from mechanical harvesting for such a task was beyond the scope of this study. Binswanger (personal communication) considers the exercise a futile one. Yet, it might be the only way to properly assess the costs and benefits of the new technology without making too many assumptions. What follows is merely a characterization of those workers who were interviewed during the survey in Muda and not necessarily those who were displaced.

Worker Characteristics

The sample consisted of 202 male and 113 female workers. For both male and female workers, the modal age group was 25 to 35 years with a mean of 31.6 years for males and 33.4 years for females (Table A-25). Over 70 percent of the workers were married (Table A-26). More than half of the workers interviewed (53.3 percent) were heads of their households and about equal proportions (22 percent) were either wives or children of heads of households (Table A-27).

Three categories of workers may be distinguished on the basis of type of work performed, namely, those who reaped (cut) only (100 percent of the female workers), those who threshed only (males) and those who performed both tasks (males). Those in the first category worked an average of 27 days during the season of the interview. The average number of days worked by the second and third categories were 25.5 and 22.8 days, respectively. A typical harvesting season extends over a period of six weeks. Table A-28 gives the distribution of the duration

Table A-25. Age of paddy farm workers by sex

Age in years	Sex[a]		Total
	Female	Male	
	---------- Percent ----------		
20 and less	10.6	11.4	11.1
20.1-25	16.8	18.8	18.1
25.1-35	36.3	38.6	37.8
35.1-45	26.7	22.8	23.8
45.1-55	6.2	7.9	7.3
Over 55	4.4	0.5	1.9
Mean	33.44	31.64	100.0

[a] Number of females sampled = 113
Number of males sampled = 202

Table A-26. Age of farm workers by marital status

Age in years	Marital status				Total
	Married	Divorced	Widow(er)	Single	
	Percent				
20 and less	0.4	0.0	0.0	50.0	11.1
20.1-25	10.9	7.7	0.0	45.6	18.1
25.1-35	47.6	53.8	0.0	4.4	37.8
35.1-45	30.1	23.1	60.0	0.0	23.8
45.1-55	8.3	15.4	40.0	0.0	7.3
Over 55	2.6	0.0	0.0	0.0	1.9
All[a]	72.7	4.1	1.6	21.6	100.0

[a] Sample size = 315 workers.

Table A-27. Relationship of workers to head of household by locality

Family position[a]	Locality			Total
	Kodiang	Titi Haji Idris	Permatang Buluh	
	Percent			
Head of household	45.7	70.2	48.2	53.3
Wife of head	37.0	13.1	18.7	22.5
Children of head	14.1	15.5	31.6	22.2
Brother or sister of head	1.1	0.0	0.7	0.6
Other	2.2	0.0	0.7	1.0
Unspecified	0.0	1.0	0.0	0.3
Total	29.2	26.7	44.1	100.0

[a] Sample size = 315 workers.

Table A-28. Number of working days, by worker type

Working days	Worker type[a]			Total
	Reap only	Thresh only	Reap and thresh	
	Percent			
10 and below	6.3	6.1	12.8	7.2
11-15	8.0	9.5	21.3	10.7
16-20	11.6	15.5	19.1	14.7
21-25	17.9	22.3	8.5	18.6
26-30	43.8	33.1	31.9	36.8
31-35	1.8	8.8	0.0	4.9
36-40	6.3	2.7	2.1	3.9
41-50	2.7	1.4	2.1	2.0
51 and above	1.8	0.7	2.1	1.3
Mean	27.0	25.5	22.8	25.6

[a] Sample size = 307
No information = 8

of labor participation of workers by worker type. The mean earnings for the season for each category were M$214.70 for reapers, M$193.60 for the threshers and M$229.00 for the mixed category. The differences were, however, not statistically significant. The overall average earning per worker in the season was M$206.00 (Table A-29). Workers in the 35 to 40 years age group appeared to be earning the most (M$227) during the season of the survey (Table A-30). Female workers also appear to earn more, on the average, than male workers from harvesting paddy (Table A-31).

An Economic Comparison between Mechanical Harvesting and Manual Harvesting

Manual harvesting consists of two major tasks, namely, reaping and threshing. Farmers who use hired labor to harvest their crop very often make separate arrangements for the two tasks, in the sense that two different groups of workers may be involved, namely, the reapers and the threshers. The cost of manual harvesting is, therefore, the combined cost of reaping and threshing. However, it should be noted that while the total cost incurred by a farmer for reaping is proportional to the harvested area, the cost for threshing is proportional to the output since it appears that the threshing effort increases with the quantity of grain. Hence, the higher the yield per acre, the higher is the cost of threshing per acre.

On the other hand, the fee charged by combine harvester operators is based on per unit area, irrespective of the yield. Hence, total harvesting cost in employing the combine is directly proportional to the area harvested.

Table A-29. Mean earnings from harvesting by worker type

Worker type	Number of workers	Mean earnings (M$)[a]
Reaper	112	214.72
Thresher	156	193.63
Reaper & thresher	47	228.94
All	315	206.40

[a] Differences are not statistically significant at 0.05 level.

Table A-30. Mean earnings from harvesting by age group

Age in years	Number of workers	Mean earning (M$)
20 and less	35	215.37
20.1-25	37	204.37
25.1-35	119	202.81
35.1-45	75	227.24
45.1-55	23	159.13
Over 55	6	166.67
All	315	206.40

Table A-31. Mean earnings from harvesting, by sex of worker

Sex	Number of workers	Mean earning (M$)
Female	113	212.29
Male	202	203.10
All	315	206.40

Let m be the cost of harvesting a unit area manually, r be the cost of reaping a unit area, w be the yield of paddy per unit area and t be the cost of threshing a unit of output. Hence, the unit area cost of manual harvesting is given by

$$m = r + tw$$

and r and t appeared to be fairly constant across farms. If the cost of harvesting a unit area by machine is h, then the "break-even yield," w*, may be determined by solving the following equation for w*:

$$r + tw^* = h.$$

Hence,

$$w^* = \frac{h - r}{t}.$$

The surveys in Muda gave the following values for h, r and t:

h = M$55 per relong;

r = M$35 per relong and

t = M$2 per gunny sack threshed.

Hence,

$$w^* = \frac{h - r}{t} = \frac{55 - 35}{2} = \frac{20}{2} = 10.$$

Using a conversion factor of 167 pounds per gunny sack, the break-even yield is 1,670 pounds per relong, or 2,349 pounds per acre. Manual labor would minimize cost for a crop that yields less than 2,349 pounds per acre. Given the average yield of 3080 pounds per acre for the Muda Scheme (MADA, 1970c:4), the cost of mechanical harvesting is definitely lower than manual harvesting for the average farmer in Muda.

The above calculation of the break-even yield is intended to show that a direct comparison between manual harvesting cost and mechanical harvesting cost must take into consideration the yield on individual farms. In the above calculation, in-field transport and winnowing costs were ignored as was the expense of providing meals and snacks to manual harvesters. If these costs were taken into account, the true cost of manual harvesting would be even higher than that given in the above calculation. Thus, the difference between manual and mechanical harvesting would be higher also.

A Regression Analysis of Labor Participation

The number of days worked by workers was regressed against several demographic variables (many of which were dummy variables) and a dummy variable denoting whether any of the workers' employers had used a combine harvester. The demographic variables included were marital status (1 if married, 0 otherwise), age in years, a sex dummy variable (1 for male, 0 for female), family size in terms of total number living in the household, number of dependent children, for married people, and four family position dummy variables as explained at the bottom of Table A-32. Wage rate was not included because of the absence of information on wage rates for the different types of work performed. Generally, in Muda, the wage rate is often quoted on a piecework basis, e.g., M$2.00 per gunny sack for threshing paddy, M$35.00 per relong for reaping and M$75.00 per relong for reaping and threshing. Had a standard wage rate been available, such as so many M$ per hour, the estimation of a labor supply would have been more meaningful. However, a pseudo-supply function or participation function may be better than none.

Table A-32. Results of regression analysis of labor participation

Explanatory variables	Coefficient	Standard error
Married (dummy)	-0.239	0.228
Age	-0.350E-3	0.008
Sex (dummy)	0.570	0.221
Family size	0.247	0.063
Number of dependent children	0.277	0.073
Family position[a]		
FP1	0.778	0.542
FP2	0.576	0.627
FP3	-0.114E-1	0.496
FP4	0.956	0.884
Employer used combine (dummy)	0.123	0.123
$R^2 = 0.143$	$\bar{R}^2 = 0.114$	$F(10, 302) = 5.031^*$

[a] FP1 = 1 if head of household, 0 otherwise
FP2 = 1 if wife, 0 otherwise
FP3 = 1 if children, 0 otherwise
FP4 = 1 if sibling to head of household
Excluded category was "other"

*Statistically significant at 0.05 level.

The regression results show that male workers worked for slightly longer duration than female workers during the season. Workers from households with the larger number of people also tend to supply more labor than those from smaller households, perhaps because of the greater need to contribute toward the family income. The number of dependents was also statistically significant and of the expected positive sign. Age did not appear to contribute to the observed differences in labor supply once the other variables were controlled. The "employer dummy" variable was not statistically significant.

The Private Contractual System

By and large, mechanical harvesting of paddy in the Muda area is being undertaken by private machine contractors. Pothecary (1970b:278, 280) believes that there is a strong case for using private contracting services in the early phase of farm mechanization and that government intervention, in the long run, is unlikely to be able to compete effectively with the more flexible and low-cost, locally based contractors. It can, however, stimulate the development of machinery services in Pothecary's view.

The study by Rayarappan (1979) appears to be the only one, to date, to address itself specifically to the contractual system and the private costs and benefits of running the combine hire business. It may be pertinent to highlight some of the findings of Rayarappan's study here in order to appreciate the overall picture of gains and losses to the various parties in this technical change.

Rayarappan (1979:14) points out that 76 percent of the private contractors are ethnic Chinese and the remainder are Malays, although

over 95 percent of the paddy farmers in Muda are Malays. Success in business among the Chinese in Southeast Asia is not a new phenomenon, however.

Over 91 percent of the contractors reside within a radius of 8.5 miles of a rural town, Tokai, about 10 miles south of Alor Setar. Over half of the contractors (58 percent) are paddy farmers with large farms, and another one-fifth operate either a sundry business or they trade in paddy--the so-called middlemen. Two-thirds of the contractors own the machine through a partnership arrangement involving about four people, on an average (Rayarappan, 1979). This finding is understandable as the purchase price of a combine is around M$170,000.

Jegatheesan (1978, personal communication) reported that the capital investment in purchasing a combine harvester (14 ft cutterbar) can be fully recovered in three harvesting seasons. According to Rayarappan's study, the internal rate of return on a combine harvester ownership was 12.44 percent (1979:57). This figure is based on an assumed salvage value of 25 percent of the cost of the machine (valued at M$170,000), an economic life of 8 years and an average annual gross income of M$55,000. The annual break-even acreage (minimum acreage) obtained by Rayarappan was 562 acres (1979:61).

There is little doubt that the combine hiring business is a lucrative one, even though capital investment is substantial by rural standards. In so far as the owner of the combine harvester is also a sundry businessman and paddy trader, double-cropping in Muda has no doubt brought him spillover benefits whose monetary value exceeds the direct benefits of the average farmer by several hundred-fold. These indirect benefits are often forgotten in grappling with the equity issue

in the context of rural development in multiracial Malaysia. However, because positive economics does not allow for the interpersonal comparison of utility, there is no clue as to who has "benefitted" most from the technical change which is manifested by the combine harvester.

MADA's Role in Mechanical Harvesting[6]

MADA was in the contract harvesting business before the private sector. In 1968 the Malaysian government received gifts of eight combine harvesters from the Belgium government (Jegatheesan, 1978, personal communication). However, because of various technical difficulties (two of them being the difficulty of obtaining spare parts and the tendency to bog in the mud), these machines went "out of circulation" within a few years of their introduction. It was not until 1976 that MADA decided to revive its contracting service, with the purchase (with a World Bank loan) of 30 small harvesters of Japanese make at a price of M$54,000 each. These smaller machines, with 32 hp engines and 6-foot cutting width, are made available to farmers through the Farmers' Associations throughout the scheme. Both members and nonmembers may hire the service of these machines.

The purchase of these small machines appears, however, to be an anachronism and contradictory to the Authority's stand that

> The present emphasis in the Muda Scheme is mechanization by means of large scale machinery through both the contractor system and group-ownership through Farmers' Association, (MADA, 1972:12)[7]

---

[6]This section is based, in part, on information provided by Encik Yahaya bin Ismail of MADA's machinery pool during Phase III of the fieldwork.

[7]The earlier preference for the "large scale" machine arose from economic comparisons between the two-wheel pedestrian tractor and the four-wheel conventional tractor which favored the bigger type of tractor (see MADA, 1971:8).

Many farmers, when asked, said the larger combines were faster and delivered grain which required less work to be done thereafter (bagging, cleaning, transporting, etc.). Rayarappan (1979:19) reports that 86 percent of the private contractors employ four workers per combine (two drivers and two attendants); the smaller machine employ only two workers to man it (MADA, personal communication). These workers are either FA members or children of members trained by MADA. The driver is paid a basic wage of M$6 a day and a commission of M$2 per relong harvested; attendants get M$5 basic wage plus M$1 per relong commission. The small machine can harvest from 150 to 200 relong per season (average for 1978-79 was 186 relong). By way of comparison, a 14-foot combine can harvest about five times the area harvested by the smaller machine in a season.

MADA also makes use of the brokerage system, although the collection of fees is done by the FA and not by the broker. Hence, brokers are paid only M$2 to M$3 per relong harvested.

Farmers are charged from M$50 to M$55 per relong harvested, which is not much lower than the fee charged by private contractors.

According to the official interviewed, MADA's decision to go for the smaller machines was based on the fact that the Authority was concerned with not breaking the hard pan in paddy soil. Ironically, MADA appears to approve the potential damage of the larger private machines.

LITERATURE CITED

Afifuddin, H. O. The Commercial Farming Behavior and Attitudes of Farmers in the Muda Scheme. MADA Publication No. 21, Alor Setar, February, 1973.

Afifuddin, H. O. "Social Implications of Farm Mechanization in the Muda Scheme." In H. Southworth and M. Barnett (Eds.), Experience in Farm Mechanization in South East Asia. New York: Agricultural Development Council, 1974:39-55.

Afifuddin, H. O., H. S. Wong and F. Kasryno. Some Aspects of Labour Utilisation in the Muda Scheme. MADA Publication No. 26, Alor Setar, August, 1974.

Ahmad, Bashir. "Farm Mechanization and Agricultural Development: A Case Study of Pakistan Punjab." Ph.D. dissertation, Michigan State University, 1972.

Ahmad, Syed. "On the Theory of Induced Innovation." Economic Journal 76(1966):344-357.

Amemiya, T. "Regression Analysis When the Dependent Variable Is Truncated Normal." Econometrica 41(1973):997-1016.

Bardhan, P. K. "Size, Productivity and Return to Scale: An Analysis of Farm-Level Data in Indian Agriculture." Journal of Political Economy 8(1973):1370-1386.

Barker, R., W. H. Meyers, C. M. Crisostomo and B. Duff. "Employment and Technological Change in Philippine Agriculture." In Mechanization and Employment in Agriculture. Geneva: International Labour Office, 1974.

Bell, C. L. G. and P. B. R. Hazell. "Measuring the Indirect Effects of an Agricultural Investment Project on Its Surrounding Region." American Journal of Agricultural Economics (forthcoming).

Berwick, E. J. H. "Mechanical Cultivation of Rice in Malaya." World Crops 3(1951):207-210.

Bhati, U. N. "Farmers' Technical Knowledge and Income--A Case Study of Padi Farmers of West Malaysia." Malayan Economic Review 18(1973): 36-47.

Billings, M. H. and A. Singh. "Employment Effects of HYV Wheat and Its Implications for Mechanization." USAID Paper, Washington, D.C., 1970.

Binswanger, H. P. "A Microeconomic Approach to Induced Innovation." Economic Journal 84(1974a):940-958.

Binswanger, H. P. "The Measurement of Technical Change Biases with Many Factors of Production." American Economic Review 44(1974b):964-976.

Binswanger, H. P. "Induced Technical Change." In H. P. Binswanger, V. W. Ruttan and Associates, Induced Innovation, Technology, Institutions and Development. Baltimore: Johns Hopkins University Press, 1978:13-43.

Blaug, N. "A Survey of the Theory of Process-Innovation." Econometrica 30(1963):13-32.

Bose, S. R. and E. H. Clark II. "Some Basic Considerations on Agricultural Mechanization in West Pakistan." Pakistan Development Review 9(1969):273-308.

Boskin, M. J. "A Conditional Logit Model of Occupational Choice." Journal of Political Economy 83(1974):389-397.

Chancellor, W. J. "Mechanization of Small Farms in Thailand and Malaysia by Tractor Hire Services." Transactions of the American Society of Agricultural Engineers 14(1971):847-854, 859.

Colmenares, J. H. Adoption of Hybrid Seeds and Fertilizers among Colombian Corn Growers--Abridged by CIMMYT. Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico City, 1975.

Cragg, J. G. "Some Statistical Models for Limited Dependent Variables with Applications to the Demand for Durable Goods." Econometrica 39(1971):829-844.

Cutie T., Jesus. Diffusion of Hybrid Corn Technology: The Case of El Salvador--Abridged by CIMMYT. Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico City, 1975.

Dagenais, M. G. "A Threshold Regression Model." Econometrica 37 (1969):193-203.

Dagenais, M. G. "Application of a Threshold Regression Model to Household Purchases of Automobiles." Review of Economics and Statistics 72(1975):275-285.

de Janvry, Alain. "Social Structure and Biased Technical Change in Argentine Agriculture." In H. P. Binswanger, V. W. Ruttan and Associates, Induced Innovation, Technology, Institutions and Development. Baltimore: Johns Hopkins University Press, 1978: 297-323.

Demir, Nazmi. The Adoption of New Bread Wheat Technology in Selected Regions of Turkey--Edited and Abridged by CIMMYT. Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico City, 1976.

Doering, Otto. "Malaysian Rice Policy and the Muda Irrigation Project." Ph.D. dissertation, Cornell University, 1973.

Donaldson, G. and J. McInerny. "The Consequences of Farm Tractors in Pakistan." Development Economics Department, IBRD, Washington, D.C., 1973.

Dorner, P. and Don Kanel. "The Economic Case for Land Reform: Employment, Income Distribution and Productivity." Land Tenure Center Reprint No. 74. University of Wisconsin. [Reprint from Land Reform, Land Settlement and Co-operatives. FAO, No. 1, 1971.]

Duff, Bart. "Output, Employment and Mechanization in Philippines Agriculture." Paper No. 75-10, International Rice Research Institute, Los Banos, Philippines, 1975.

Evenson, R. E. and H. P. Binswanger. "Technology Transfer and Research Allocation." In H. P. Binswanger, V. W. Ruttan and Associates, Induced Innovation, Technology, Institutions and Development. Baltimore: Johns Hopkins University Press, 1978:164-211.

Fair, R. C. "A Note on the Computation of the Tobit Estimator." Econometrica 45(1977):1723-1727.

Falcon, W. P. "Agricultural and Industrial Relationship in West Pakistan." Journal of Farm Economics 49(1967):1139-1154.

Far Eastern Economic Review, Yearbook 1978. Hong Kong: Far Eastern Economic Review, Ltd., 1978.

Fellner, W. "Two Propositions in the Theory of Induced Innovations." Economic Journal 71(1961):305-308.

Foster, J. "Mechanical Harvesting." In Mechanization and the World's Rice. Conference Report, Massey-Ferguson (Export) Ltd. and FAO, United Nations, September, 1967:94-96.

Gafsi, Salem. Green Revolution: The Tunisian Experience--Abridged by CIMMYT. Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico City, 1976.

Gemmill, G. and C. Eicher. "The Economics of Farm Mechanization and Processing in Developing Countries." Seminar Report No. 4, Agricultural Development Council, New York, December 1973.

Gerhart, John. The Diffusion of Hybrid Maize in Western Kenya--Abridged by CIMMYT. Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico City, 1975.

Gisser, Micha. "Schooling and the Farm Problem." Econometrica 33 (1965):582-592.

Gittinger, J. P. "Planning Characteristics of Low Income Agriculture." In W. W. McPherson (Ed.), Economic Development of Tropical Agriculture. Gainesville: University of Florida Press, 1968:240-266.

Goldberger, A. S. Econometric Theory. New York: John Wiley & Sons, Inc., 1964.

Gotsch, Carl H. "Technical Change and the Distribution of Income in Rural Areas." American Journal of Agricultural Economics 54(1973): 326-341.

Griliches, Zvi. "Hybrid Corn: An Exploration in the Economics of Technological Change." Econometrica 25(1957):501-522.

Hayami, Y. and V. W. Ruttan. Agricultural Development: An International Perspective. Baltimore: Johns Hopkins University Press, 1971.

Helleiner, Gerald K. "Smallholder Decision Making: Tropical African Evidence." In Lloyd G. Reynolds (ed.), Agriculture in Development Theory. New Haven: Yale University Press, 1975:27-52.

Hicks, J. R. The Theory of Wages. London: Macmillan and Co., Ltd., 1932.

Hrabouszky, J. P. and T. K. Moulik. "Economics and Social Factors Associated with the Adoption of an Improved Implement: A Study of the Olpad Thresher in India." Agricultural Development Council, New Delhi, May, 1967.

Inukai, I. "Farm Mechanization, Output and Labour Input: A Case Study in Thailand." International Labour Review 101(1970):443-473.

Jegatheesan, S. The Contribution of Economic Research to the Rice Mechanization Process in West Malaysia with Specific Reference to the Muda Irrigation Scheme. MADA Publication No. 14, Alor Setar, Kedah, August, 1971.

Jegatheesan, S. "The Economics of Mechanization in Rice Double-Cropping in the Muda Irrigation Scheme." In H. Southworth and M. Barnett (Eds.), Experience in Farm Mechanization in South East Asia. New York: Agricultural Development Council, 1974:31-38.

Jegatheesan, S. Land Tenure in the Muda Irrigation Scheme. MADA Monograph No. 29, Alor Setar, June, 1976.

Jegatheesan, S. The Green Revolution and the Muda Irrigation Scheme. MADA Monograph No. 30, Alor Setar, March, 1977.

Johnson, Thomas. "Qualitative and Limited Dependent Variables in Economic Relationships." Econometrica 40(1972):455-462.

Kennedy, Charles. "Induced Bias in Innovation and the Theory of Distribution." Economic Journal 74(1966):541-547.

Len, Swee Chooi. "The Use of the Massey-Ferguson 39-6 Rice Combine in the Rice Areas of Malaya." Unpublished Report, Department of Agriculture, Malaysia, circa. 1967.

Long, Erven J. "The Economic Basis of Land Reform in Underdeveloped Economies." Land Economics 37(1961):113-123.

Maddala, G. S. Econometrics. New York: McGraw-Hill Book Co., 1977a.

Maddala, G. S. "Identification and Estimation Problems in Limited Dependent Variable Models." In Alan S. Blinder and Philip Friedman (Eds.), Natural Resources, Uncertainty and General Equilibrium Systems: Essays in Memory of Rafael Lusky. New York: Academic Press, 1977b:219-239.

Maddala, G. S. and F. Nelson. "Analysis of Qualitative Variables." Unpublished NBER Working Paper Series No. 70, Computer Research Center for Economics and Management Science, NBER Inc., October, 1974.

Mangahas, Mahar. "An Economic Analysis of the Diffusion of New Rice Varieties in Central Luzon." Ph.D. dissertation, University of Chicago, 1970.

Mansfield, E. "Technical Change and the Rate of Imitation." Econometrica 29(1961):741-766.

Martin, Marshall A. "The Income Distribution Impacts of the Adoption of Mechanical Harvesting of Cotton in the United States." M.S. thesis, Purdue University, 1972.

McPherson, W. W. and J. Wayne Reitz. "Education, Research and Agricultural Development in Tropical Countries." Institute Agronomico Per L'Oltremare. Firenze: Tipografia R. Coppini & C., 1974.

Mellor, J. W. The Economics of Agricultural Development. Ithaca: Cornell University Press, 1966.

Merrill, William C. "The Impact of Agricultural Mechanization on Employment and Food Production." Occasional Paper No. 1, Economics and Sector Planning Division, USAID, Washington, D.C., September, 1975.

Meyer, Paul L. Introductory Probability and Statistical Applications. Reading, MS: Addison-Wesley Publishing Co., 1965.

Mid-Term Review of the Third Malaysia Plan, 1976-80. Kuala Lumpur: Government Printer, 1979.

Miklius, W. and K. L. Casavant. "Estimation of Demand for Transportation of Agricultural Commodities." (Paper prepared for U.S. Department of Agriculture under Research Agreement No. 12-17-01-7-336-X.) Department of Agricultural Economics, Washington State University, Pullman, Washington (undated).

Ministry of Agriculture, Malaysia. Statistical Digest 1975. Kuala Lumpur: Author, 1975.

Mohamed, Khairi H. "Problems of Training Extension and Farmer Organizations in Promoting Mechanization." In H. Southworth and M. Barnett (Eds.), Experience in Farm Mechanization in South East Asia. New York: Agricultural Development Council, 1974:22-30.

Mosher, Arthur T. Creating a Progressive Rural Structure to Serve Agriculture. New York: Agricultural Development Council, 1969.

Muda Agricultural Development Authority. "An Economic Report on Combine Harvesting of Padi in the Muda Irrigation Scheme." (Mimeo), Alor Setar, December, 1970a.

Muda Agricultural Development Authority. Farm Mechanization in the Muda Scheme. MADA Publication No. 7, Alor Setar, August, 1970b.

Muda Agricultural Development Authority. The Muda Irrigation Scheme. MADA Publication No. 4, Alor Setar, May, 1970c.

Muda Agricultural Development Authority. Combined Farm Management Studies in the Muda Area Pilot Projects. MADA Publication No. 1, Alor Setar, February, 1970d.

Muda Agricultural Development Authority. The All Terrain Vehicle--Its Potential as a Multi-Purpose Prime Mover in Rice Production. MADA Publication No. 12, Alor Setar, August, 1971.

Muda Agricultural Development Authority. "Cost of Padi Production Survey Off-Season 1977." Planning and Evaluation Division, Alor Setar, February, 1978.

Nerlove, Marc and S. James Press. "Univariate and Multivariate Log-linear and Logistic Models." Rand Report No. R-1036-EDA/NIH, Santa Monica, December, 1973.

Ooi, Jin Bee. Land, People and Economy in Malaya. London: Longmans, 1963.

Phipps, L. J. Mechanics in Agriculture. Danville, IL: Interstate Printers and Publishers, Inc., 1967.

Pothecary, B. P. "Does Agricultural Mechanization Increase Unemployment?" World Crops 22(1970a):419-420.

Pothecary, B. P. "The Contractor's Role in Mechanizing Small Farms." World Crops 22(1970b):278, 280.

Raup, Philip M. "Land Reform and Agricultural Development." In H. M. Southworth and B. F. Johnston (Eds.), Agricultural Development and Economic Growth. Ithaca: Cornell University Press, 1967.

Rayarappan, Balan. "An Economic Analysis of the Contractual Padi Combine Harvesting System in the Muda Irrigation Project." Unpublished Project Paper, Universiti Pertanian Malaysia, March, 1979.

Rogers, Everett M. and F. F. Shoemaker. Communication of Innovations: A Cross-Cultural Approach, 2nd Ed. New York: Free Press, 1971.

Rothschild, K. W. The Process of Innovation. Oxford: Basil Blackwell, 1954.

Ruttan, V. W. and H. P. Binswanger. "Induced Innovation and the Green Revolution." In H. P. Binswanger, V. W. Ruttan and Associates, Induced Innovation, Technology, Institutions and Development. Baltimore: Johns Hopkins University Press, 1978.

Salter, W. E. G. Productivity and Technical Change. London: Cambridge University Press, 1960.

Schiekele, Rainer. Agrarian Revolution and Economic Progress: A Primer for Development. New York: Praeger Publishers, 1969.

Schmidt, P. and R. P. Strauss. "The Prediction of Occupation Using Multiple Logit Models." International Economic Review 16(1975a): 471-486.

Schmidt, P. and R. P. Strauss. "Estimation of Models with Jointly Dependent Qualitative Variables: A Simultaneous Logit Approach." Econometrica 43(1975b):745-755.

Schmitz, A. and D. Seckler. "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester." American Journal of Agricultural Economics 52(1970):569-579.

Singh, Inderjit and R. H. Day. "Capital-Labor Utilization and Substitution in Punjab Agriculture." Economics and Sociology Paper No. 70, Department of Agricultural Economics and Rural Sociology, Ohio State University, 1972.

Southworth, H. and M. Barnett (Eds.). Experience in Farm Mechanization in South East Asia. New York: The Agricultural Development Council, 1974.

Staub, W. J. and M. G. Blase. "Induced Technological Change in Developing Agricultures: Implications for Income Distribution and Agricultural Development." The Journal of Developing Areas 8(1974): 581-591.

Tamin, M. and R. Noah. "Rice Mechanization: Technical and Economic Issues for Policy Consideration." In H. Southworth and M. Barnett (Eds.), Experience in Farm Mechanization in South East Asia. New York: The Agricultural Development Council, 1974:9-21.

Taylor, D. C., K. M. Noh and M. A. Hussein. "An Economic Analysis of Irrigation Development in Malaysia." Unpublished paper, Faculty of Resource Economics and Agribusiness, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia, 1979.

Theil, Henri. Economics and Information Theory. Amsterdam: North-Holland Publishing Co., 1967.

Theil, Henri. Principles of Econometrics. New York: John Wiley and Sons, Inc., 1971.

Third Malaysian Plan, 1976-80. Kuala Lumpar: Government Printer, 1975.

Thirsk, W. R. "Income Distribution, Efficiency and the Experience of Colombian Farm Mechanization." Paper No. 33, Program of Development Studies, Rice University, Texas, 1972.

Timmer, C. P. "Choice of Technique in Indonesia." Discussion Paper No. 72-4, Food Research Institute, Stanford University, 1972.

Tobin, J. "Estimation of Relationships for Limited Dependent Variables." Econometrica 26(1958):24-36.

Tsuchiya, K. "A Test of the Hypothesis of Economic Rationality in the Mechanization of Small Scale Farming in Japan." Journal of Faculty of Agriculture, Kyushu University 16(1971):1-20.

Van, T. K. "The Breeding and Selection of Two New Hybrid Varieties, Malinja and Mahsuri for Double Cropping in the States of Malaya." Malayan Agricultural Journal 45(1966):332-344.

Warriner, Doreen. "Land Reform and Economic Development." In Carl Eicher and Lawrence Witt (Eds.), Agriculture in Economic Development. New York: McGraw-Hill, 1964:283-286.

Welch, F. "Education in Production." Journal of Political Economy 78 (1970):35-58.

Wirasinghe, S. "Adoption of High Yielding Rice Farming Practices by the Rice Farmers in the Amparai District, Republic of Sri Lanka." M.S. thesis, University of Philippines at Los Banos, October, 1977.

Wong, I. F. T. The Present Land Use of West Malaysia, 1966. Kuala Lumpur: Ministry of Agriculture and Land, 1971.

Zellner, A. and T. H. Lee. "Joint Estimation of Relationships Involving Discrete Random Variables." Econometrica 33(1965):382-394.

ADDITIONAL REFERENCES

Binswanger, H. P. The Economics of Tractors in South Asia. New York: The Agricultural Development Council and ICRISAT, 1978.

Cox, D. R. The Analysis of Binary Data. London: Methuen and Co., 1970.

Duff, Bart. "Mechanization and Use of Modern Rice Varieties." In IRRI, Economic Consequences of the New Rice Technology. Los Banos, Philippines, 1978:145-164.

McFadden, Daniel. "A Comment on Discriminant Analysis 'versus' Logit Analysis." Annals of Economic and Social Measurement 5(1976):511-523.

Press, S. James and Sandra Wilson. "Choosing between Logistic Regression and Discriminant Analysis." Journal of the American Statistical Association 73(1978):699-705.

Westin, R. "Predictions from Binary Choice Models." Journal of Econometrics 2(1974):1-16.

BIOGRAPHICAL SKETCH

Ahmad Mahdzan Bin Ayob was born August 14, 1942, at Jejawi, Perlis, Malaysia. He received early education in Perlis and at the Royal Military College in Malaysia (1958-62). In 1963 he received a Colombo Plan scholarship to study in New Zealand, and was conferred the Bachelor of Horticultural Science degree by the University of Canterbury, Christchurch, in May 1967. He then returned to Malaysia to serve the Federal Agricultural Marketing Authority as a marketing economist. In September, 1968, he joined the College of Agriculture, Malaya (later to become Universiti Pertanian Malaysia) as a lecturer.

In the Fall of 1969 he received a Ford Foundation scholarship to do a master's degree in agricultural economics at the University of Florida and was graduated in June, 1971. He then returned to Malaysia to resume his service with the Universiti Pertanian Malaysia. In January, 1974, he helped set up the Faculty of Resource Economics and Agribusiness at the UPM and served as Acting Dean of that faculty until December, 1974.

During the periods January, 1975, to May, 1977, and January to March, 1980, he was back at the University of Florida pursuing his doctorate degree in food and resource economics, for which he is now a candidate.

Ahmad Mahdzan Bin Ayob is the author of two university textbooks in his native language--Pengurusan Ladang [Farm Management] (1976, rev.

1980) and Teori Mikroekonomi (1979)--and several semi-academic (in his native language) and journal articles published in his region. He is a member of the Editorial Board of Pertanika, an agricultural science journal published by the Universiti Pertanian Malaysia.

The author is married, has three children and lives in Petaling Jaya, Malaysia.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. W. McPherson

W. W. McPherson, Chairman
Graduate Research Professor of Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

M. R. Langham

M. R. Langham
Professor of Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

R. D. Emerson

R. D. Emerson
Associate Professor of Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John E. Reynolds

J. E. Reynolds
Associate Professor of Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

F. O. Goddard
Associate Professor of Economics

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

March, 1980

Dean, College of Agriculture

Dean, Graduate School